THE WATER QUALITY OF TROUT LAKE NORTH BAY

Ministry
of the
Environment

Ontario

THE WATER QUALITY

OF

TROUT LAKE

NORTH BAY

NORTHEASTERN REGION

AND

LABORATORY SERVICES BRANCH

1979

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ACKNOWLEDGEMENTS

The water quality survey of Trout Lake was a co-operative venture involving the Technical Support Section of the Northeastern Region, the North Bay District Office and the Microbiology Section of the Laboratory Services Branch.

The authors, G. Myslik, G. S. Hendry, and S. Janhurst wish to acknowledge the contributions of the study participants in the collection of samples, enumeration of bacteriological parameters, preparation of figures and charts, reviews of the draft reports and finally, the typing of the manuscript.

INTRODUCTION

Trout Lake is an important natural resource to the North Bay area. It functions as the city water supply, and a good quality recreational area while supporting a moderately high density of both permanent and recreational housing along its shoreline. Because of local concern for the maintenance of a high order of water quality, a request for a major water quality survey was submitted by the Corporation of the City of North Bay.

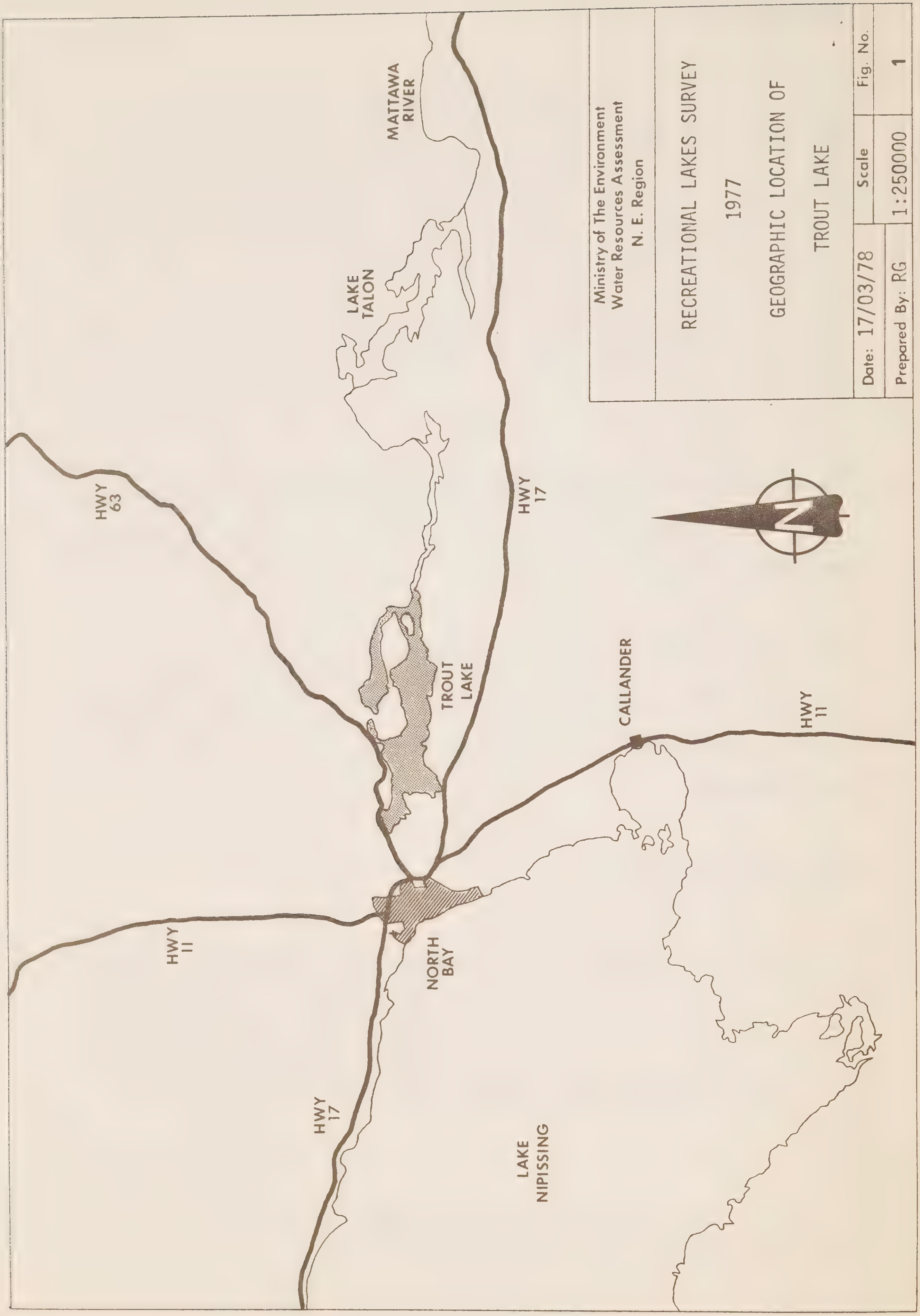
The objectives of the survey were to define existing levels of chemical and bacteriological water quality and to identify any problem areas.

Data obtained were used to calculate a phosphorus budget for the lake. The potential effect of further housing development on this budget and the likely impact on existing water quality were examined.

STUDY AREA DESCRIPTION

Trout Lake is located in the eastern end of the City of North Bay approximately 4.5 km east of the Highway 11 and 63 interchange (Figure 1). It is the headwater lake for the Mattawa River system which flows through Lake Talon to the Ottawa River.

The surficial geology of the Trout Lake drainage basin is characterized by glacial deposits. The topography of the drainage basin is varied. To the north of Trout Lake are



MATTAWA RIVER
LAKE TALON
HWY 63
HWY 17
TROUT LAKE
CALLANDER
HWY 11
HWY 11
NORTH BAY
HWY 17
LAKE NIPISSING
N
Ministry of The Environment
Water Resources Assessment
N. E. Region
RECREATIONAL LAKES SURVEY
1977
GEOGRAPHIC LOCATION OF
TROUT LAKE
Date: 17/03/78
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Scale
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found densely forested high Precambrian hills overlain with glacial deposits while to the south the land is much flatter and is characterized by rock outcrops, sandy deposits and some swampy areas.

Trout Lake's physical characteristics are listed below. Because the lake is composed of two separate non-interacting basins, data are presented for both Trout Lake proper and Four Mile Bay.

<u>Trout Lake (main body)</u>

Watershed Area	5763 hectares
Surface Area	1368 hectares
Mean Depth	17.21 m
Maximum Depth	69 m
Volume	23.5×10^7 m^3
Flushing Rate	.13/year

<u>Four Mile Bay</u>

Watershed Area	5398 hectares
Surface Area	306 hectares
Mean Depth	15.62 m
Maximum Depth	34 m
Volume	47.7×10^6 m^3
Flushing Rate	.53/yr

Trout Lake has numerous small inlets scattered about its perimeter. The major inflow is Four Mile Creek which empties to the west end of Four Mile Bay. The only outlet is the Mattawa River at the east end of Trout Lake.

Based on Ministry of Natural Resources Survey data there are 9 commercial resorts and more than 650 cottage units and permanent residences. There is a float plane base in Delaney Bay.

Trout Lake is classified as a cold water fishery containing lake trout and whitefish. It is known mainly for the presence of Atlantic salmon and also provides angling opportunity for warm water species including northern pike, yellow pickerel, maskinonge and smallmouth bass.

Recreational activities on Trout Lake include swimming, boating, sailing, fishing and waterskiing in the summer, with snowmobiling and icefishing during the winter.

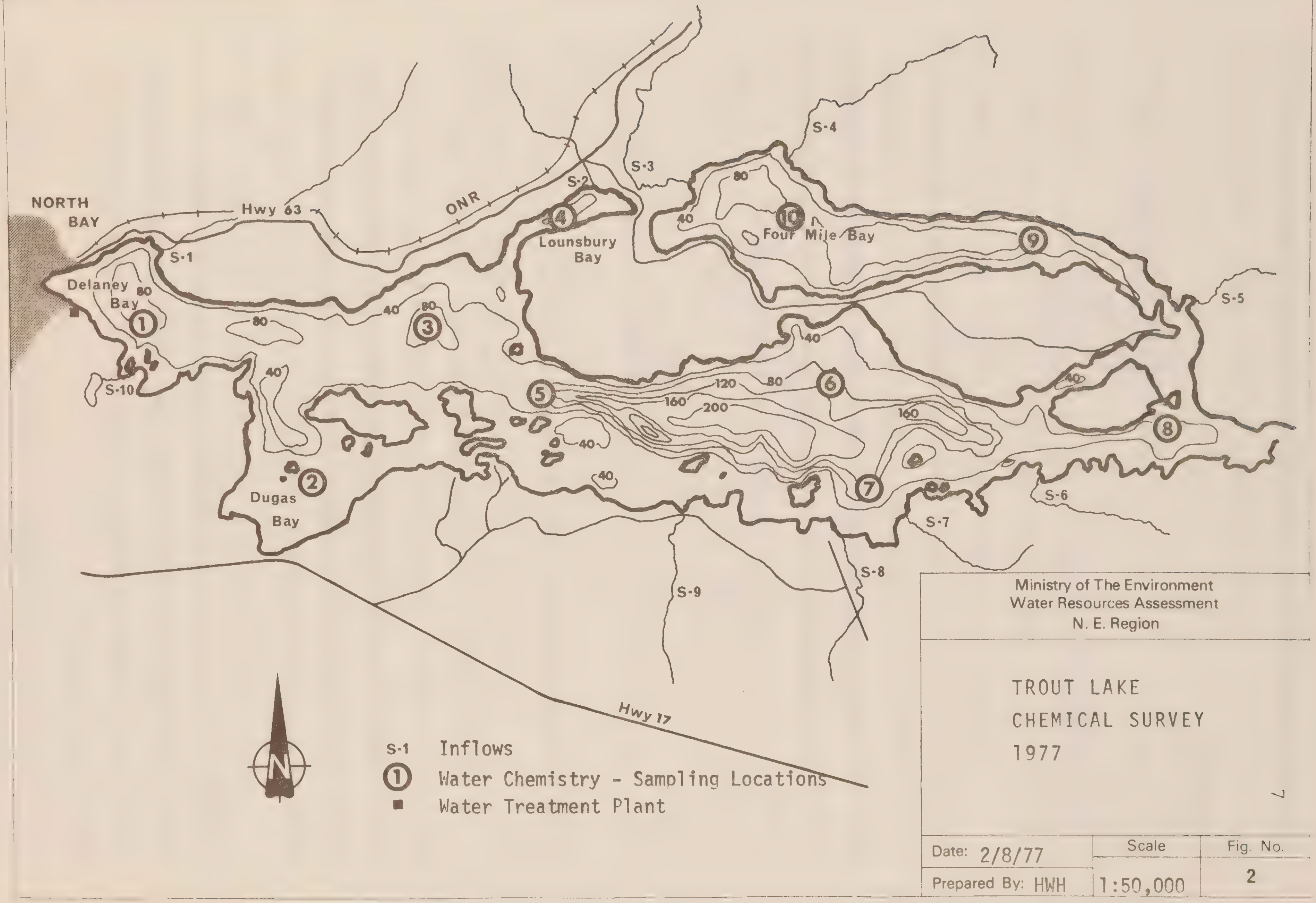
The main concerns expressed by local residents involved general pollution inputs from cottages, drainage from area roads and the preservation of a high quality municipal water supply.

SURVEY PROCEDURES

(a) Chemical Water Quality

Ten lake stations and ten inflowing streams were sampled during the spring and summertime period of 1977 (Figure 2).

On June 10, July 19 and September 16, composite samples of the euphotic zone (depth of effective light penetration where biological activity occurs) and from 1 metre off the lake bottom were taken for water chemistry analysis. Inflowing streams were sampled June 11 and July 19.


NORTH BAY
Delaney Bay
Dugas Bay
Lounsbury Bay
Four Mile Bay
Hwy 63
ONR
Hwy 17
S-1
S-2
S-3
S-4
S-5
S-6
S-7
S-8
S-9
S-10
1
2
3
4
5
6
7
8
9
10
40
80
120
160
200
S-1 Inflows
1 Water Chemistry - Sampling Locations
■ Water Treatment Plant
N
Ministry of The Environment
Water Resources Assessment
N. E. Region
TROUT LAKE
CHEMICAL SURVEY
1977
Date: 2/8/77
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Chemical analyses performed on water samples included:

hardness	nitrite
alkalinity	nitrate
pH	organic carbon
conductivity	inorganic carbon
colour	calcium
total phosphorus	magnesium
total Kjeldahl nitrogen	sulphate
ammonia	chloride
	iron

Because of the presence of railway lines over which metal concentrates are transported within the Trout Lake watershed and the relative proximity of the Sudbury smelting operations, the concentrations of the following heavy metals in Trout Lake and its inflowing streams were investigated.

copper	zinc
nickel	cadmium
lead	arsenic

Water transparency was measured on seven separate occasions in 1977. A Secchi disc (20 cm diameter metallic disc printed in alternate black and white quadrants) was lowered into the water until it disappeared from view. At the same time, water samples for chlorophyll a determination (the green pigment in microscopic plants known as algae) were secured as euphotic zone composites.

Dissolved oxygen and temperature profiles at one metre depth intervals were developed at each lake sampling location during the chemical surveys by means of a Y.S.I. Model 54 combination meter.

All chemical analyses were carried out at the Ministry of the Environment Laboratory in Toronto.

Chemical Tests and Interpretation

The determination of chemical water quality involves evaluation of the concentrations and distribution of particular chemical species. Characterization parameters which are used to "describe" a water include:

Hardness, the soap consuming ability of a water.

Calcium and Magnesium, the major cations contribution to hardness.

Conductivity, a measure of the ability of water to pass an electric current. It is used as an indication of quantities of dissolved substances.

pH, a measure of acidic or basic properties of water. A reading above 7 is basic while values less than 7 are acidic.

Colour, a determination of the intensity of the yellow-orange hue contributed to lakes by organic material or iron.

Alkalinity, a measure of a water's ability to resist pH change from acidic inputs.

Nutrient parameters including; total phosphorus, the four inter-related forms of nitrogen, and inorganic carbon are used to determine the enrichment or trophic status of a lake. Nutrient poor or oligotrophic lakes are usually very clean and clear while eutrophic or nutrient rich lakes are characterized by turbid water caused by extensive growths of algae and aquatic weeds.

Other chemical species examined are iron, which can impart colour, odour and taste to natural water, and chloride and

sulphate which can be indicative of pollution inputs resulting from the activities of man.

Where the possibility of mining related or waste rock drainage exists, the concentrations of heavy metals which can have either chronic or acute toxic effects on plant and animal life are investigated.

Indications of lake trophic status and water quality are also obtained from the investigation of biological and physical conditions.

Primary biological activity is evaluated by measuring the concentration of chlorophyll a the green pigment in algae (tiny plants suspended in the water column). At the same time, water clarity or transparency is determined by lowering a black and white Secchi disc until it disappears from view.

The mid to late summer vertical distributions of dissolved oxygen and water temperature can be used to explain many of the conditions encountered and to estimate the potential for the occurrence of specific water quality problems.

b) Bacteriological Water Quality

Measurement of bacterial numbers over five consecutive days at a sampling location is regarded as a reliable number to be taken to provide a sound value of the bacterial population density. When many lake stations are sampled in this manner, a reproducible picture of bacteriological water quality is obtained.

The western and eastern halves of Trout Lake were examined separately. In 1977 two consecutive five-day bacteriological water quality surveys were conducted between June 2 and June 11, and July 14 and July 23, inclusive.

The bacteriological sample stations were located at midlake, inflows, outflows and in areas considered representative of the various degrees of shoreline development found on the lake. Samples were taken at 70 shoreline locations, 4 midlake and 4 depth stations (Figure 3). The samples were taken 7 to 10 metres from shore, one metre below the surface, as well as one metre above the bottom at the midlake stations. At one midlake station (40), water was sampled 5 metres from the lake bottom.

In order that the bacteriological water quality of the North Bay water supply could be evaluated, samples of raw and finished water were taken. Samples were obtained from:

a) depth midlake station 40 (approximate location where water is pumped into the municipal drinking water plant).

b) raw water sample before being treated (from the 60' inlet).

c) chlorinated water sample (from the water treatment plant tap) in a sample bottle containing sodium thio-sulphate.

FIGURE 3 - LOCATION OF BACTERIOLOGICAL SAMPLING STATIONS ON TROUT LAKE

LEGEND

P
C (8) CH — SAMPLING STATION
D

C — CHEMICAL SAMPLE
P — PROFILE
CH — CHLOROPHYLL SAMPLE
D — DEPTH STATION
BACTERIOLOGICAL SAMPLES
TAKEN AT ALL STATIONS

1 0 1 2 KILOMETRES

MINISTRY OF THE ENVIRONMENT	
RECREATIONAL LAKES PROGRAM TROUT LAKE 1977 WATER QUALITY SURVEY	
SCALE: AS SHOWN	
DRAWN BY: A.R.S.	DATE AUG., 1978
CHECKED BY:	DRAWING Nº 8326

Bacteria were enumerated using the following methodologies:

1) Total coliform (TC) bacteria were determined as a count of dark red colonies with gold metallic sheen grown on a membrane filter (Gelman GN6) with m-Endo LES agar. (M.O.E. 1976).

2) Fecal coliform (FC) bacteria were determined as a count of acid producing yellow to yellowish-green colonies grown on a membrane filter with MacConkey broth at 44.5°C. (M.O.E. 1976).

3) Fecal streptococcus (FS) bacteria were obtained from a count of pink or red colonies grown on a membrane filter with m-Enterococcus agar. (M.O.E. 1976).

4) Pseudomonas aeruginosa (PsA) were determined as a count of flat, tan to brown colonies grown on a membrane filter with MPA medium. (Levin and Cabelli 1972).

5) Heterotrophic bacteria (HB) were obtained from a total count of colonies from surface inoculated plates of modified Foot and Taylor medium, incubated for seven days at 20°C. (Hendry 1977).

6) Presence-Absence (P-A) Test. The presence-Absence Test will more readily isolate bacteria from samples where the bacterial density is low; for example, about 1/100 mL. This test has proven more sensitive for detecting pollution indicator bacteria in drinking water than the membrane filter technique. (M.O.E. 1976).

For the lake stations the population densities of the coliform groups of organisms were determined on each sample. Fecal streptococci were determined only on samples taken from inflowing streams and from a limited number of shoreline locations (Stations 5,6,25,44 and 40D Figure 3).

In addition three water samples were taken over the two five-day surveys of Trout Lake to test its bacteriological drinking water suitability as indicated in the (P-A) test.

Bacteriological Tests and Interpretation

Three indicator bacteria, total coliform, fecal coliform and fecal streptococcus are all indigenous to man and other warm-blooded animals, and are found in the colon and feces in tremendous numbers. In addition, human/animal feces usually contain a variety of pathogens (diesease causing microorganisms). Since many diseases common to man can be transmitted by feces, the probability of occurrence of these diseases is highest in areas where the water is contaminated with fecal material. The presence of these indicator organisms is used in water quality assessment to detect and indicate contamination from fecal material and hence the potential presence of pathogens.

The population densities of *Pseudomonas aeruginosa* and heterotrophic bacteria are also investigated. *Pseudomonas aeruginosa* is a pathogen which is found largely in the feces of man and may lead to infections when encountered in water. Heterotrophic bacteria are found in the greatest numbers in nutrient-rich waters. They can be used as indicators of trophic status.

The densities of the indicator bacteria in water will fluctuate considerably in response to changing environmental conditions. Therefore, microbiological surveys require the collection of many samples from several stations over an extended period of time.

The large amount of data obtained during sampling periods are reduced by calculations to meaningful and easily managed

statistics. These data are then evaluated by the following statistical techniques. The geometric mean, the most appropriate central value, and variance are calculated for the values of each of the indicator bacteria and Pseudomonas aeruginosa at every station. Statistically significant variations in the bacterial densities between stations, or groups of stations, are determined by a One-Way Analysis of Variance and Bartlett's Test of Homogeneity. By these means, the data from each station are tested against those of every other station until all stations with similar geometric mean densities are separated into groups (Group A, B).

The group results and those for individual stations are identified by different stippling on summary maps. Within each stippled area, the group geometric mean applies for each type of bacteria unless otherwise indicated by individual station values. The areas of better or worse bacterial densities are defined by the group geometric mean densities; and so, any inputs of bacterial contamination, and the area they affect, are identified.

The effect of present development on the lake can be estimated by comparison of developed and undeveloped sections of the lake, and by comparison to bacteriological levels found in undeveloped lakes.

Surface Water Chemistry Characteristics

Results of chemical anlyses for samples obtained from the euphotic zone and 1 metre off the bottom of Trout Lake on June 10, July 19, and September 16 are shown in Tables A, B, and C in the Appendix.

Surface water chemical data characterize Trout Lake as a softwater (hardness 16-22 mg/L), lightly coloured (colour 5-20 units), near neutral body of water (pH 6.6-7.9 units) with a moderate load of dissolved substances (conductivity 54-83 umhos/cm) and a fair buffering capacity (alkalinity 8-12 mg/L). The nutrient elements were present in varying amounts. Phosphorus (0.001-0.018 mg/L) was detected in low amounts while nitrogen levels (0.3-0.5 mg/L) were moderately high. Inorganic carbon concentrations (1-6 mg/L) were relatively low.

Concentrations of iron in the surface waters were low ranging from 0.02-0.05 mg/L and were well below the drinking water criterion of 0.30 mg/L.

The major cations, calcium (4.4-6.0 mg/L) and magnesium (1.1-1.8 mg/L) were present in moderately low concentrations while concentrations of chloride (3.1-8.6 mg/L) were moderate and sulphate (10-12.5 mg/L) was low.

The water chemistry characteristics of Four Mile Bay were different from the main body of Trout Lake. Because of lower concentrations of most dissolved substances including calcium, magnesium, chloride and sulphate, Four Mile Bay (stations 9 and 10) was more dilute (conductivity 55 umhos/cm).

Sampling location 8, near the outlet was influenced by the outflow from Four Mile Bay; therefore, water chemistry at this location appeared to be a mixture of the two basins.

Temperature and Dissolved Oxygen

Oxygen and temperature profiles for the ten lake stations were developed on June 10, July 19 and September 16. Results are shown in the Appendix.

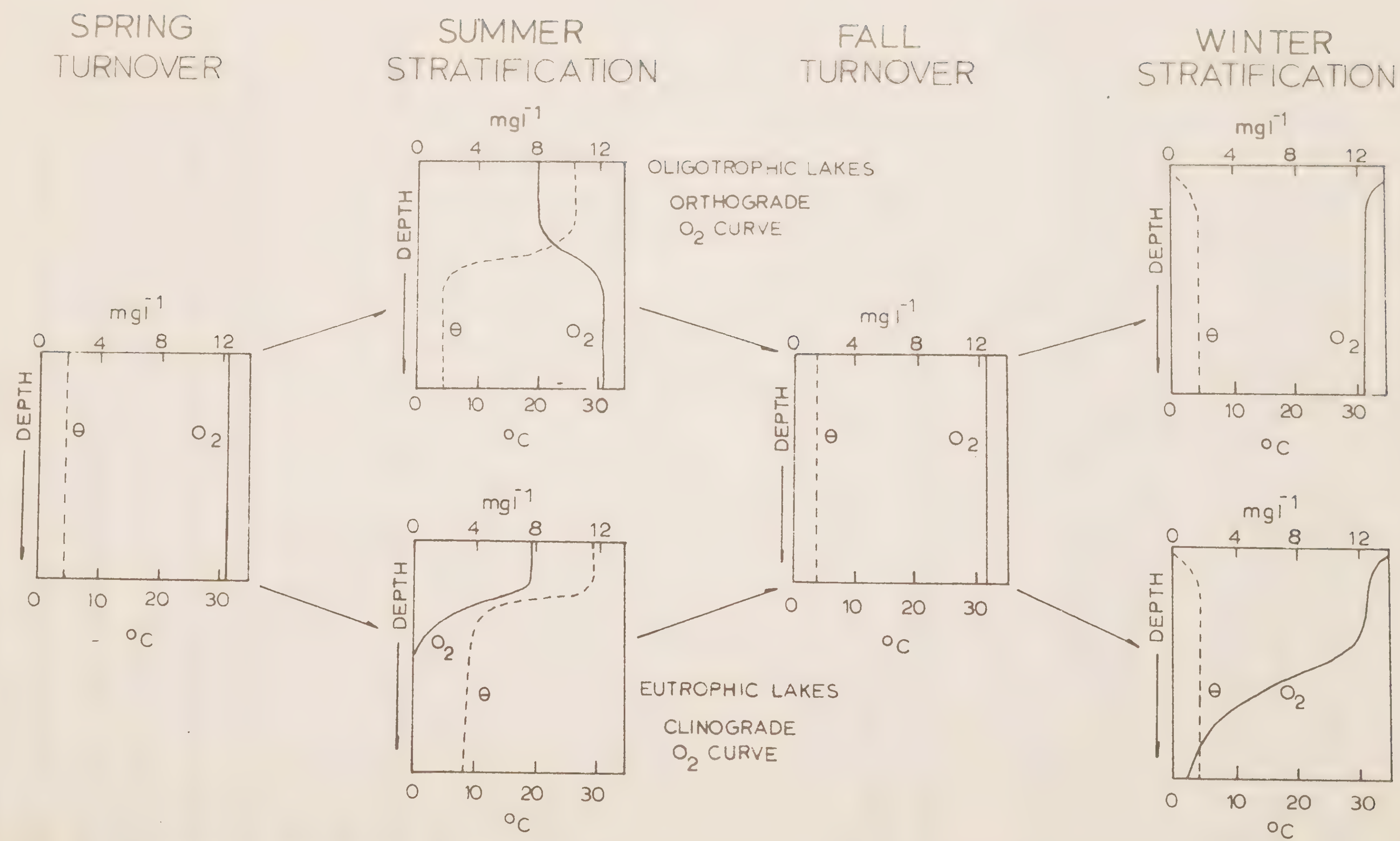
Ministry of the Environment dissolved oxygen objectives for cold water biota (lake trout) are temperature related and are stated below.

Dissolved Oxygen Concentration Cold Water Biota

Temperature °C	Oxygen mg/L
0	8
5	7
10	6
15	6
20	5
25	5

Except for station 8 on September 16 when concentrations of 5 mg/L were found near the bottom, the amount of dissolved oxygen present throughout the lake was well above the minimum objective.

The distribution of dissolved oxygen from surface to bottom during periods of thermal stratification (partitioning of the water column due to differences in temperature) can be used as an indication of trophic status (degree of nutrient enrichment). A diagram showing the relationship between trophic status and vertical oxygen-temperature distributions is presented as Figure 4.



IDEALIZED VERTICAL DISTRIBUTIONS OF OXYGEN CONCENTRATIONS (O_2) AND TEMPERATURE (θ) OF OLIGOTROPHIC (NUTRIENT POOR) AND EUTROPHIC (NUTRIENT ENRICHED) LAKES

FIGURE 4

During the summer stratification period, the vertical oxygen distribution in oligotrophic (nutrient poor) lakes is termed orthograde which means that dissolved oxygen concentrations in the cold bottom waters are higher than in the warmer zone.

In eutrophic (nutrient rich) lakes where recreational activities like swimming and boating may be made less pleasant due to turbid water, algae blooms and weed growths, vertical dissolved oxygen distributions are clinograde. Dissolved oxygen concentrations decline from surface to bottom due to the oxidation of organic matter settled on the bottom. In extreme situations (Figure 4) oxygen levels below the warm surface layer may drop to zero making the deep areas of the lake unsuitable for the support of aquatic life.

The oxygen-temperature profiles shown in the Appendix reveal the existence of favourable orthograde oxygen distributions at each sampling location on June 10. By July 19, orthograde oxygen distributions were still apparent in Trout Lake stations 3, 5, 6, 7 and at station 10 in Four Mile Bay. Station 8 in Four Mile Bay showed an increase in oxygen concentration at the thermocline (zone of rapid temperature decline at a depth of 8 m) followed by a reduction of oxygen with increasing depth. The shallow sampling locations where depths near 10 m were observed also revealed dissolved oxygen increases in the zone where water temperature began to decline.

The dissolved oxygen pulses at the thermocline areas of the shallow locations were thought to be concentrations of photosynthesizing (oxygen producing) algae.

On September 16, mature oxygen and temperature profiles were traced. At the shallow sampling locations (stations 1, 2, 4, 9) temperatures were almost uniform from surface to bottom. Dissolved oxygen concentrations were similarly uniform except at station 9 in Four Mile Bay, where a slight decline was observed at the bottom.

At the deep sampling stations 3, 5, 6 and 7, the thermoclines were located at a depth of approximately 12 m. Water temperatures dropped from 18°C at the surface to 8°C below a depth of 15 m. Dissolved oxygen concentrations had shifted from the orthograde pattern to an almost uniform surface to bottom distribution. Conditions remained favourable for the support of cold-water fisheries as minimum oxygen concentrations near 9 mg/L were well above the 6 mg/L requirement.

The sampling locations with intermediate depth of water column (station 8 and 10) exhibited the less favourable clinograde oxygen distribution with decreasing oxygen concentrations below the thermocline. However, this condition is thought to be normal in basins of intermediate depth (up to 25 m) and cannot be interpreted as a sign of eutrophication.

Overall, dissolved oxygen concentrations in Trout Lake were found to be very good approximating the orthograde distributions found in high quality oligotrophic lakes.

Water Chemistry Evaluation

On the basis of anlytical data the water chemistry of Trout Lake was easily separated into two distinct units: Trout Lake proper, and Four Mile Bay. Within these units there was little seasonal or vertical variation in water chemistry (Tables A, B, C, Appendix).

Within the characterization parameter group, hardness, alkalinity, conductivity, calcium, and magnesium concentrations in surface and near-bottom water samples were essentially similar throughout the survey. In Four Mile Bay, concentrations of the aforementioned chemical parameters were lower than in the main body of the lake.

Ministry of the Environment objectives pertinent to recreational suitability and the protection of aquatic life state that pH should be maintained within a range of 6.5 to 8.5 units. Throughout the survey, pH values in the surface waters (6.6-7.9), were within the favourable range.

The pH reduction in the bottom waters of stations 3, and 5 through 10 during the September sampling period is a commonly observed phenomenon resulting from the decomposition of settled organic matter.

Colour in natural surface waters is primarily associated with the presence of humic acids derived from the decomposition of plant material. Colour determinations, which measure the intensity of the yellow-brown hue, include the colour due to

dissolved substances as well as the colour contributed by suspended matter. Most naturally coloured waters are harmless; however, a drinking water objective of 5 Hazen units is specified for aesthetic reasons.

Determinations of colour in June and July indicated that there was a light yellow hue present which was slightly more pronounced in July. Four Mile Bay exhibited a greater colour intensity than the rest of the lake.

Chloride and sulphate are two common anions the presence of which in high concentrations is often related to the influence of man.

Chloride poses no direct health hazard but a salty taste may be noticed if concentrations exceed 250 mg/L. Urban runoff often contains high concentrations of chloride in the winter time due to road salt application.

The influence of salt application on roadways within the Trout Lake watershed is apparent since chloride concentrations in the main body of the lake (8.5 mg/L) are much higher than in Four Mile Bay (3.3 mg/L) which has a slightly smaller drainage area with fewer roads. Overall, chloride concentrations in Trout Lake are low.

Sulphate is a widely distributed ionic component in natural waters normally varying between 10 and 80 mg/L. It can also be added to a watershed through atmospheric fallout originating in the oxidation of sulphur dioxide from industrial sources.

Sulphate concentrations in Trout Lake proper were very low (12.5 mg/L) as were the values found in Four Mile Bay (11 mg/L). Sulphate concentrations did not appear to be influenced by industrial activity.

The remaining characterization parameters investigated included organic carbon and iron.

Organic carbon is a measure of carbonaceous components and can be related to water colour. The concentrations of organic carbon observed (2-8 mg/L) were considered to be low. There was little difference between surface and near-bottom concentrations.

Iron is a component of hemoglobin and an essential element for all life forms. It is non-toxic at high levels but objectionable in domestic water supplies because of the colour and the bitter taste it imparts. Iron can also be released from the lake bottom during the bacterial decomposition of settled organic matter under anoxic (no oxygen) conditions. During periods of lake turnover, the iron may reach surface waters and lead to unpleasant odours and shoreline discolouration.

In Trout Lake, no problems with iron accumulation were observed. Concentrations in surface and near-bottom waters were much below the drinking water objective of 0.30 mg/L.

Nutrient Characteristics

Phosphorus is considered to be the main nutrient regulating

primary biological activity (algae growth). In natural waters concentrations of phosphorus less than 0.010 mg/L are low and not problematic whereas concentrations higher than 0.020 mg/L may lead to problem algae growths.

From June through September, total phosphorus concentrations were usually very low; however, an individual high value of 0.018 mg/L was detected in the surface sample at station 5 in September. The overall average phosphorus concentrations observed during the summer period were well below 0.010 mg/L. No build-ups of phosphorus were seen in the bottom waters.

In the normal course of decomposition of nitrogenous organic matter, nitrogen goes through the following changes. Total organic nitrogen is transformed through bacterial action to ammonia which is oxidized through the unstable nitrite form to nitrate.

Concentrations of the organic total Kjeldahl nitrogen form were very low throughout the lake in June (0.16-0.23 mg/L), low in July in the main body of the lake (0.18-0.25) while approaching moderate levels in Four Mile Bay (0.30 mg/L), and moderately low (0.18-0.31 mg/L) in September. Accumulation of nitrogenous organic matter in the bottom waters was not apparent.

Ammonia concentrations in surface and bottom waters varied from 0.002 to 0.030 mg/L and were considered to be low.

Concentrations of the unstable intermediate, nitrite, were very low and never exceeded 0.002 mg/L.

Because oxygen concentrations in the water column were high, most of the nitrogen was found in the highly oxidized nitrate form. Concentrations of nitrate in the surface and bottom waters in June were moderately high (0.208-0.273 mg/L). Surface water concentrations decreased during the summer through utilization by algae and vascular aquatic plants; however, concentrations still remained within the moderate range (0.048-0.118 mg/L) as a result of a low order of biological activity.

Concentrations of nitrate in the bottom waters of the deep sampling locations remained moderately high throughout the summer.

Inorganic carbon is a measure of the carbon in the bicarbonate form that is readily available to support biological productivity. Concentrations in surface and bottom waters generally remained in the low 2-4 mg/L range.

Inflowing Stream Water Chemistry

Ten inflows shown in Figure 2 were sampled in June and July. Analytical data are summarized in Table D and E in the Appendix. The significance of the chemical composition of the inflowing streams is discussed relative to the chemistry of the receiving water bodies.

The major inflows were S-1 (Lees Creek) which empties to Delaney Bay and S-3 (Four Mile Creek) which flows to Four Mile Bay.

Conductivity readings which are a measure of dissolved substances in the inflows were found to be variable. The streams designated S-1, S-2, S-3, S-5, S-8, S-9 and S-10 contained higher loads of dissolved substances than the receiving basins while S-4, S-6 and S-7 were more dilute.

The stream with the highest conductivities (144-175 umhos/cm) was S-2 (Hogan Creek) which empties to Lounsbury Bay. The hardness components calcium and magnesium were present in quantities approximately twice those of Lounsbury Bay. The major contributors to the increased dissolved solids load of S-2 were sulphates which were detected at concentrations between 45 and 60 mg/L. The remaining inflows contained low sulphate levels which approximated the concentrations detected in Trout Lake.

Chlorides in concentrations between 8.9-15 mg/L, which are higher than the receiving water average of 8.5 mg/L found in Trout Lake, appeared to be gaining access by means of inflows S-1, S-8-9-10. The watersheds of these streams are subjected to the influence of greater human activity (roads, dwellings) than inflow S-5 where a very low chloride concentration of 0.4 mg/L was found.

In Four Mile Bay, inflow S-3 with a chloride concentration ranging from 6.8-10.5 mg/L, was an input while S-4, with a concentration of 3.3 mg/L was similar to the existing chloride level of the Bay.

Nutrient access by means of inflowing streams did not appear to be a factor as nitrogen in the total Kjeldahl, ammonia, nitrite and nitrate forms was present in low to moderate concentrations. Inflow total phosphorus concentrations were generally low except for streams S-6-7-8-9 where moderate levels of approximately 0.030 mg/L were observed.

Inorganic carbon concentrations for all inflows were considered to be low.

Heavy Metal Content

Since the Trout Lake watershed contains railway lines over which metal concentrates are transported and because of the relative proximity of the Sudbury smelting operations, the presence of potentially toxic heavy metals in the lake and its inflows was investigated.

Results of metal analyses for lake surface water stations are shown in Tables F and G in the Appendix while stream water metal concentrations are summarized in Tables H and I.

Concentrations of all metals in the surface waters of Trout Lake and Four Mile Bay were well below drinking water criteria.

Nickel, lead, cadmium and arsenic were found in very low concentrations at or below the detection limits of the analytical methods available. On the other hand, copper (0.02-0.07 mg/L) and zinc (0.04-0.08 mg/L) were present in what were considered to be moderately high concentrations for surface waters. The highest zinc concentrations (0.07--0.08 mg/L) consistently occurred in Four Mile Bay and in Lounsbury Bay (sampling station 4, 0.06-0.07 mg/L).

Investigation of the metal concentrations of inflowing streams revealed one existing problem and a potential trouble area. As found in the lake, concentrations of nickel, lead, cadmium and arsenic were at or below analytical detection limits for all streams while copper and zinc were present above detection limits. Dangerously high concentrations of zinc were observed at station S-2, Hogan Creek (7.6-8.6 mg/L) while Four Mile Creek S-3, (0.34-0.42 mg/L) also contained what are considered to be concentrations with toxicity potential to many aquatic life forms. Both of these zinc inputs appeared to have a slight influence on receiving water chemistry as the highest lake-water zinc concentrations were detected in Lounsbury and Four Mile Bays.

The source of the high zinc concentrations in S-2 and S-3 is attributed to metal concentrates deposited within their watersheds through train derailments. The effect of one such derailment on the biology and water chemistry of Hogan Creek S-2 is discussed in the Appendix.

Chlorophyll a - Secchi Disc

Averages of lake-wide determinations of chlorophyll a and Secchi disc visibilities are shown in Table J in the Appendix and are summarized in Figure 5. For ease of interpretation, results from stations not representing individual basins were grouped for plotting in Figure 5.

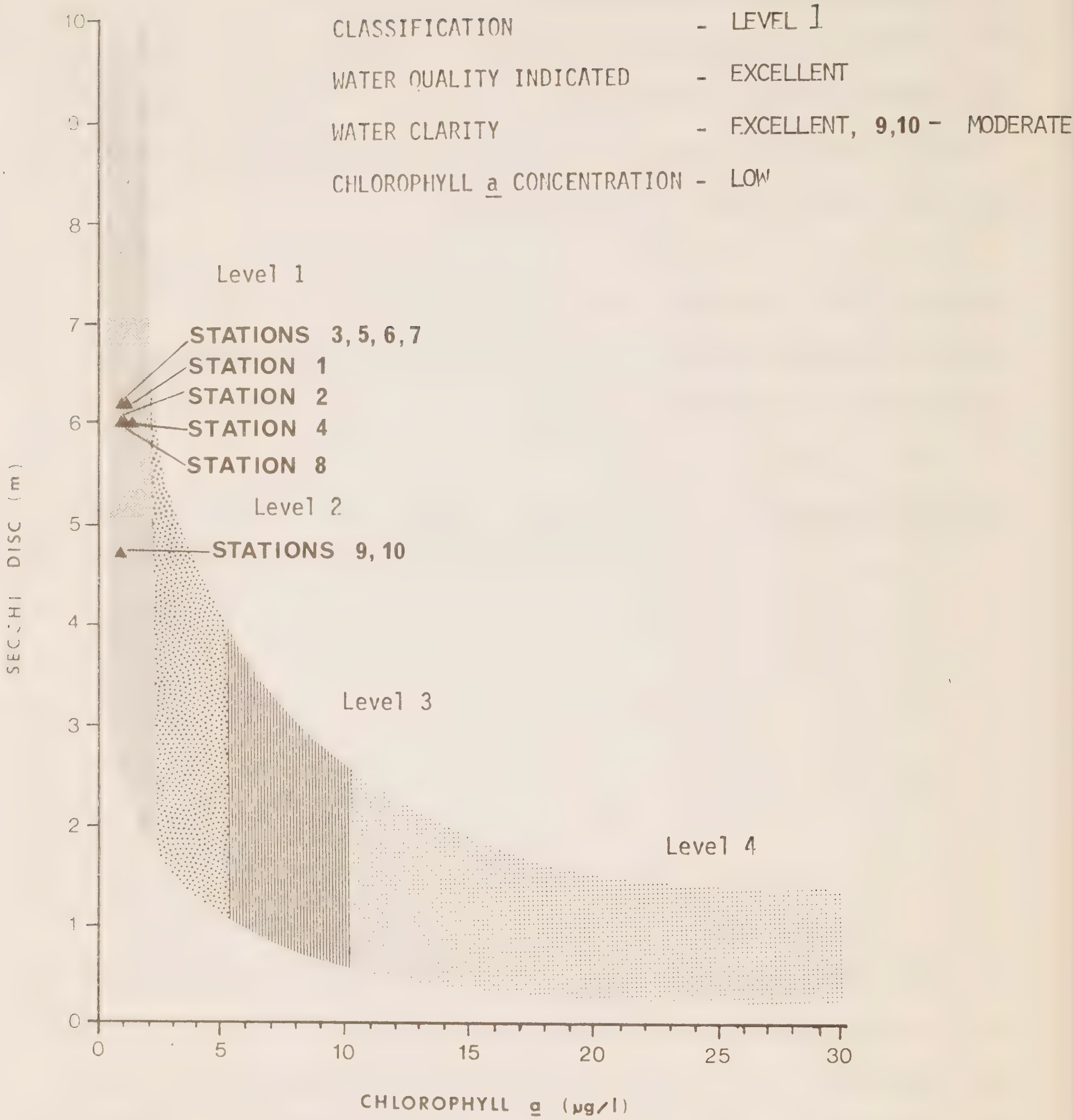
Combined data included open lake stations 3, 5, 6 and 7 along with locations 9 and 10 in Four Mile Bay. Station means are tabled below.

Sampling Station	Average Secchi Disc Visibility (m)	Chlorophyll a (ug/L)
1	6.2	1.1
2	6.0	1.0
4	6.0	1.4
3,5,6,7	6.2	1.0
8	6.0	1.1
9,10	4.8	.9

As shown, average chlorophyll a concentrations were low at all sampling stations. Secchi disc visibility (water clarity) was excellent in Trout Lake proper and moderate in Four Mile Bay. The reduced light penetration in Four Mile Bay did not appear to be caused by increased standing crops of algae.

Because chlorophyll a determinations at the Central Laboratory of the Ministry of the Environment were subject to errors induced by the filters used in 1977, it was concluded that the chlorophyll a concentrations reported were low. For

TROUT LAKE 1977



LAKE CLASSIFICATION BASED ON CHLOROPHYLL a SECCHI DISC RELATIONSHIP

KEY: Secchi Disc Visibility (m)

- 5+ excellent
- 2.5 - 5 moderate
- 1 - 2.5 low
- 0 - 1 poor

Chlorophyll a Concentration (ug/l)

- 0 - 2 low
- 2 - 5 moderate
- 5 - 10 high
- 10+ excessive

FIGURE 5

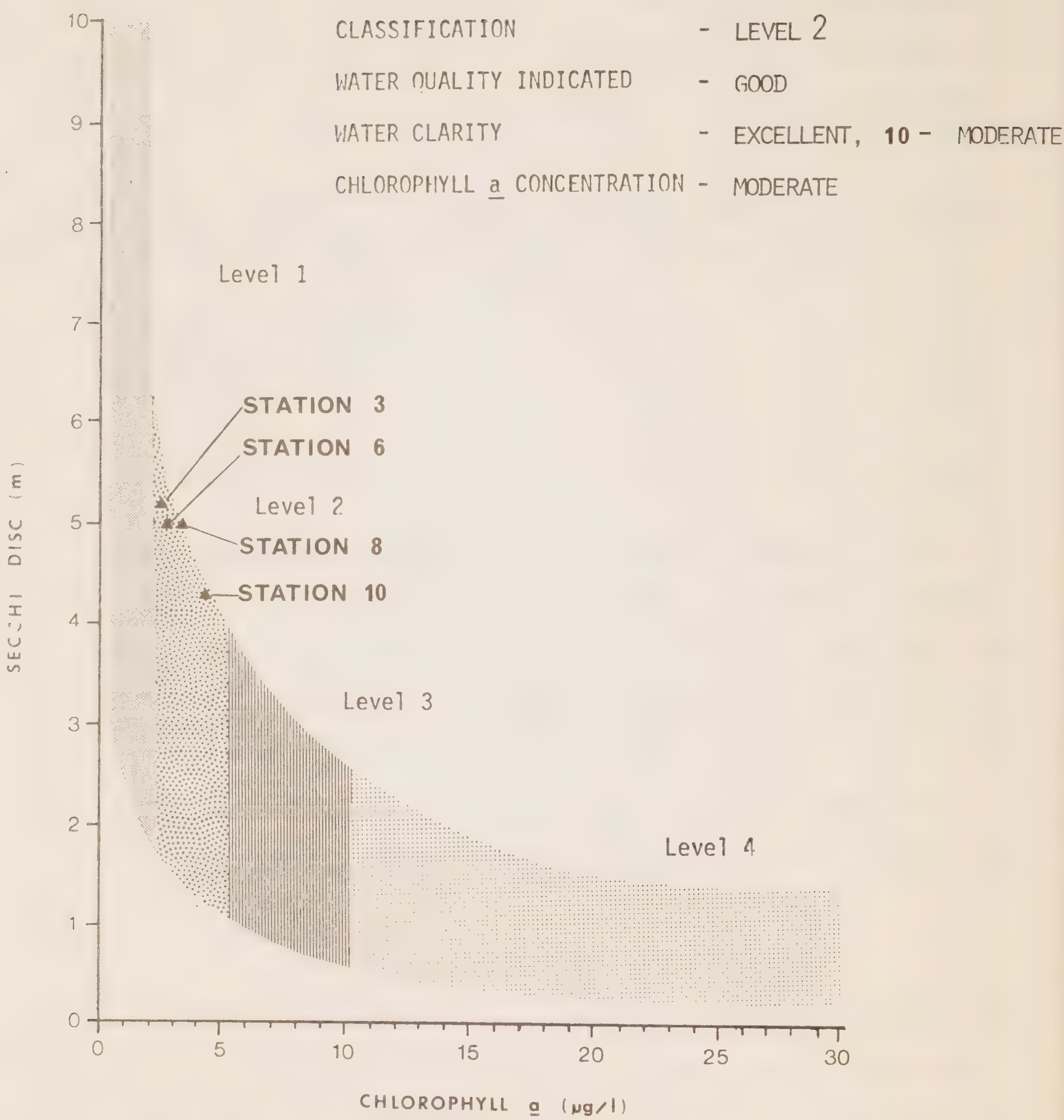
this reason results of a cottagers "self-help" sampling program undertaken during the June-August period in 1975 are included for comparison. Locations sampled were equivalent to stations 3, 6, 8 and 10 of the 1977 survey. Results are summarized below and plotted in Figure 6.

Station	Chlorophyll a (ug/L)			Secchi Disc Visiblity (m)		
	Low	Mean	High	Low	Mean	High
3	0.6	2.4	4.6	3.8	5.2	6.2
6	0.7	2.7	6.7	3.5	5.0	6.0
8	0.6	3.4	7.1	4.0	5.0	6.0
10	0.6	4.3	9.8	3.5	4.3	6.0

As shown, concentrations of chlorophyll a in the open lake sampling stations 3 and 6 were moderate while water clarity was excellent. At station 8, concentrations of chlorophyll a were still moderate but higher than in the main body of Trout Lake. In Four Mile Bay, average chlorophyll a concentrations were at the high end of the moderate range and Secchi disc visibilities were also in the moderate range.

Because the chlorophyll a sampling program in 1975 was terminated in mid August thereby excluding the average standing crop of algae for the remainder of the ice free season, and because the sunny, warm and dry conditions in 1975 were particularly conducive to the production of algae it is thought that chlorophyll a levels found in 1975 were higher than would be expected under normal climatic conditions. It is expected that the normal chlorophyll a summer average will fluctuate within the low to moderate range.

TROUT LAKE 1975



LAKE CLASSIFICATION BASED ON CHLOROPHYLL a SECCHI DISC RELATIONSHIP

KEY: Secchi Disc Visibility(m)

- 5+ excellent
- 2.5 - 5 moderate
- 1 - 2.5 low
- 0 - 1 poor

Chlorophyll a Concentration(ug/l)

- 0 - 2 low
- 2 - 5 moderate
- 5 - 10 high
- 10+ excessive

FIGURE 6

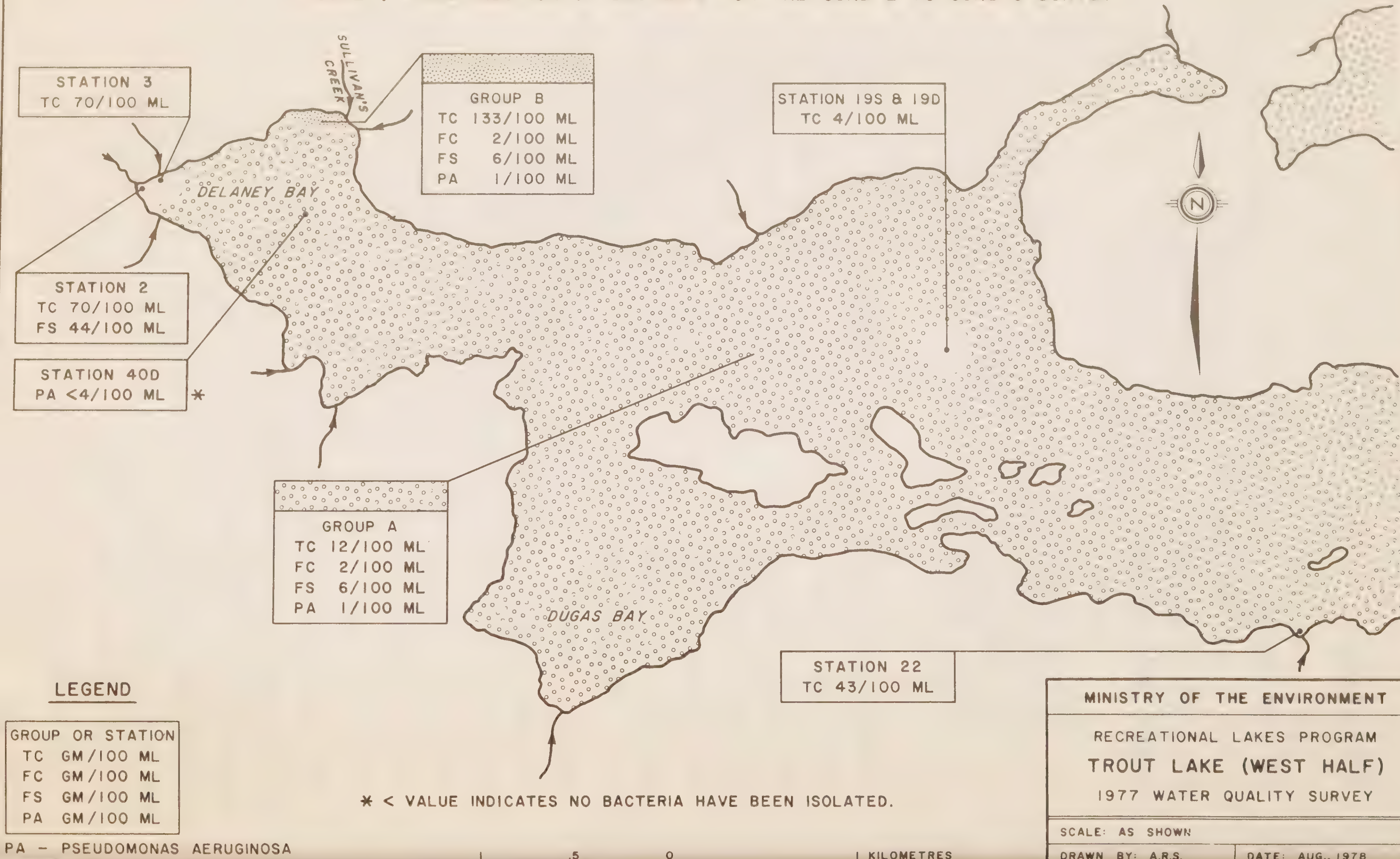
Bacteriology

In June and July of 1977 the bacteriological water quality of Trout Lake was generally good and within the Ministry of the Environment (M.O.E.) Microbiology Criteria for Total Body Contact Recreational Use which state:

> "Where ingestion is probable, recreational waters can be considered impaired when the coliform (TC), fecal coliform (FC) and/or enterococcus (fecal streptococcus, FS) geometric mean density exceeds 1,000, 100 and/or 20 per 100 ml respectively, in a series of at least ten samples per month..."

In June the geometric mean bacterial densities for the western half of the lake were 12 TC, 2 FC, 6 FS and 1 PsA per 100 ml (Group A, Figure 7). In the northwestern part of the lake, inflowing water from a culvert and nearby Sullivan's Creek (Group B, Figure 7) showed elevated total coliform densities 133 TC per 100 ml, but fecal coliform fecal streptococcus and *P. aeruginosa* densities did not differ from those of Group A. Several other inflowing streams, two in the west (Stations 2 and 3) and one along the middle of the south shore near the Ministry of Natural Resources (M.N.R.) Park (Station 22) also had increased total coliform levels ranging from 43 to 70 TC per 100 ml. Fecal streptococcus densities at Station 2 rose to 44 FS per 100 ml. Inflows often have higher bacterial levels than the rest of the lake as they may transport materials such as soil, decaying matter and possibly animal and human wastes into the lake. At the midlake depth station 40, *P. aeruginosa* was not isolated; and at the midlake station 19, the surface and bottom waters had low total coliform densities of 4 TC per 100 ml. The geometric mean density of all heterotrophic bacteria was 484 HB per ml.

FIGURE 7 - DISTRIBUTION OF BACTERIA FOR THE JUNE 2 TO JUNE 6 SURVEY



MINISTRY OF THE ENVIRONMENT

RECREATIONAL LAKES PROGRAM

TROUT LAKE (WEST HALF)

1977 WATER QUALITY SURVEY

SCALE: AS SHOWN

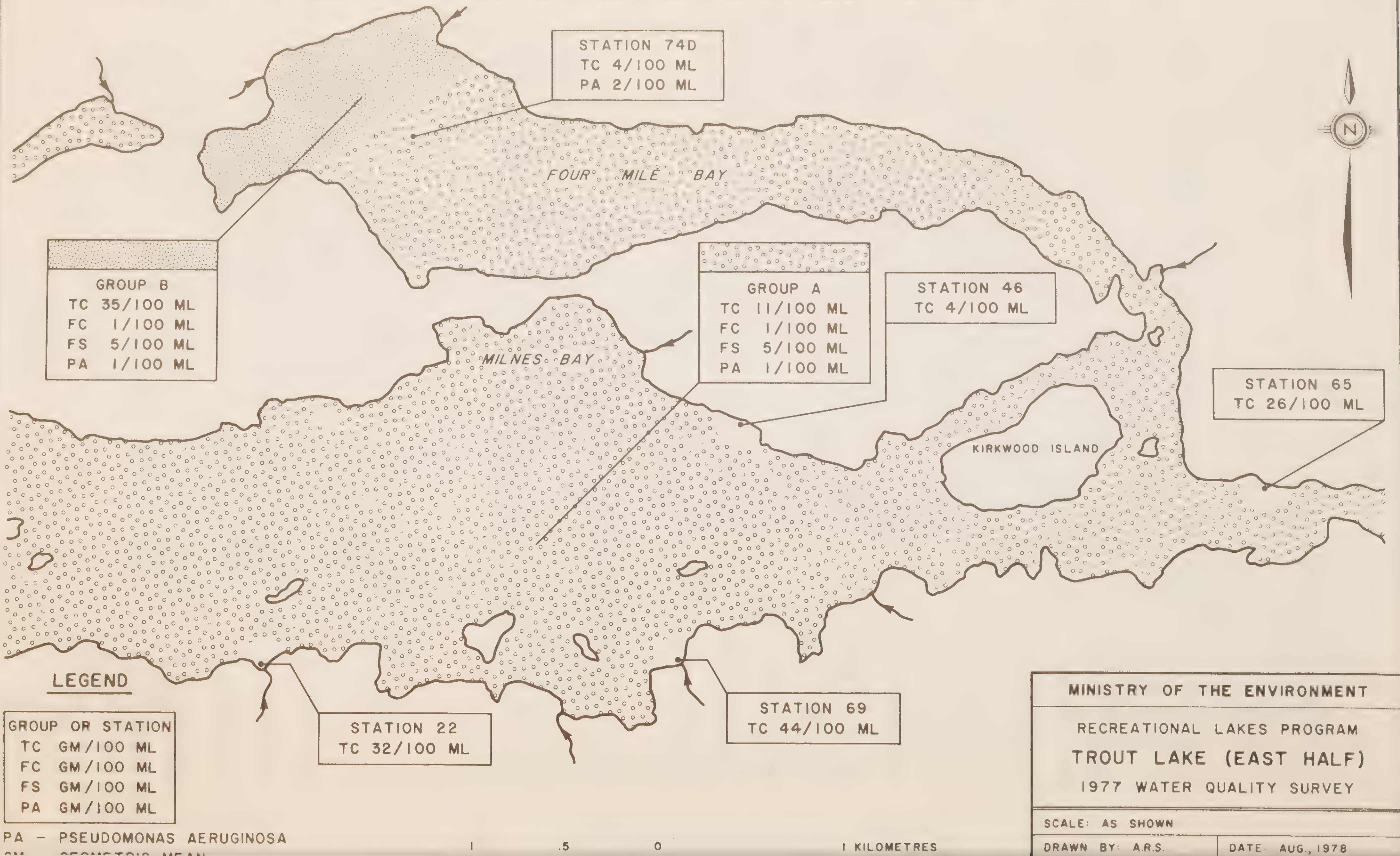
DRAWN BY: A.R.S. DATE: AUG., 1978

In June the geometric mean bacterial densities in the eastern half of the lake in the main body of water were 11 TC, 1 FC, 5 FS and 1 PsA per 100 ml (Group A, Figure 8). In the northwest part of Four Mile Bay elevated total coliform levels of 35 TC per 100 ml were found (Group B, Figure 8), but, the fecal coliform, fecal streptococcus and P. aeruginosa gave densities that were the same as those found in the main body of water. The bottom waters at the midlake station in this area (Station 74) had low total coliform densities of 4 TC per 100 ml, and increased P. aeruginosa levels of 2 PsA per 100 ml. At the mouths of two inflowing streams situated on the southern perimeter of the main part of the lake (Stations 22 and 69), increased total coliform concentrations of 32 and 44 TC per 100 ml respectively were found. On the opposite shore, a cottaged area (Station 46) had low total coliform densities of 4 TC per 100 ml.

Elevated total coliform densities of 26 TC per 100 ml were detected east of Kirkwood Island on the north bank (Station 65). The heterotrophic bacterial geometric mean was 596 HB per ml.

The bacterial levels for the overlapping stations 21, 22 and 23 did not change between surveys of the east and west halves of the lakes with the exception of the fecal streptococcus densities. High fecal streptococcus levels were found at the inflowing stream (Station 22) during the first part of the survey but these concentrations decreased considerably during the latter part of the survey.

FIGURE 8 - DISTRIBUTION OF BACTERIA FOR THE JUNE 7 TO JUNE 11 SURVEY



In July the geometric mean bacterial densities for the main body of water in the western half of the lake were 17 TC, 1 FC, 14 FS and 1 PsA per 100 ml (Group A, Figure 9). A small area where two inflowing streams enter into the south western portion of the lake, had total coliform densities of 44 TC per 100 ml (Group B, Figure 9), however, fecal coliform, fecal streptococcus and *P. aeruginosa* levels were the same as those found in the main body of water. Several inflowing streams and shoreline locations along the northern part of the lake had elevated coliform densities. The inflowing streams in the northwest region near the M.N.R. Park (Stations 1, 2 and 3) had total coliform levels of 94, 347 and 68 TC per 100 ml respectively. Stations 2 and 3 had fecal coliform levels of 4 FC per 100 ml. A little northeast at the Trout Lake Marina (Station 4) fecal coliform densities increased to 5 FC per 100 ml. Further east along the same shoreline at a cottaged area (Station 13) total and fecal coliform densities were 59 TC and 5 FC per 100 ml. The midlake stations 40 and 19 had low total coliform densities of 6 and 5 TC per 100 ml respectively. *P. aeruginosa* levels increased to 2 PsA per 100 ml in the bottom waters at station 19. The heterotrophic bacterial densities were 335 HB per ml.

In July the geometric mean bacterial densities for the eastern half of the lake were 9 TC, 1 FC, 21 FS and 1 PsA per 100 ml (Group A, Figure 10). In the Milnes Bay area, an inflowing stream (station 45) had higher coliform levels of 31 TC and 3 FC per 100 ml than those found in the main body of water (Group A). Across the lake, several isolated stations along the southern shoreline (stations 22, 73, 71 and 68) had increased coliform densities ranging from 23 to 30 TC per 100 ml.

FIGURE 9 - DISTRIBUTION OF BACTERIA FOR THE JULY 14 TO JULY 18 SURVEY

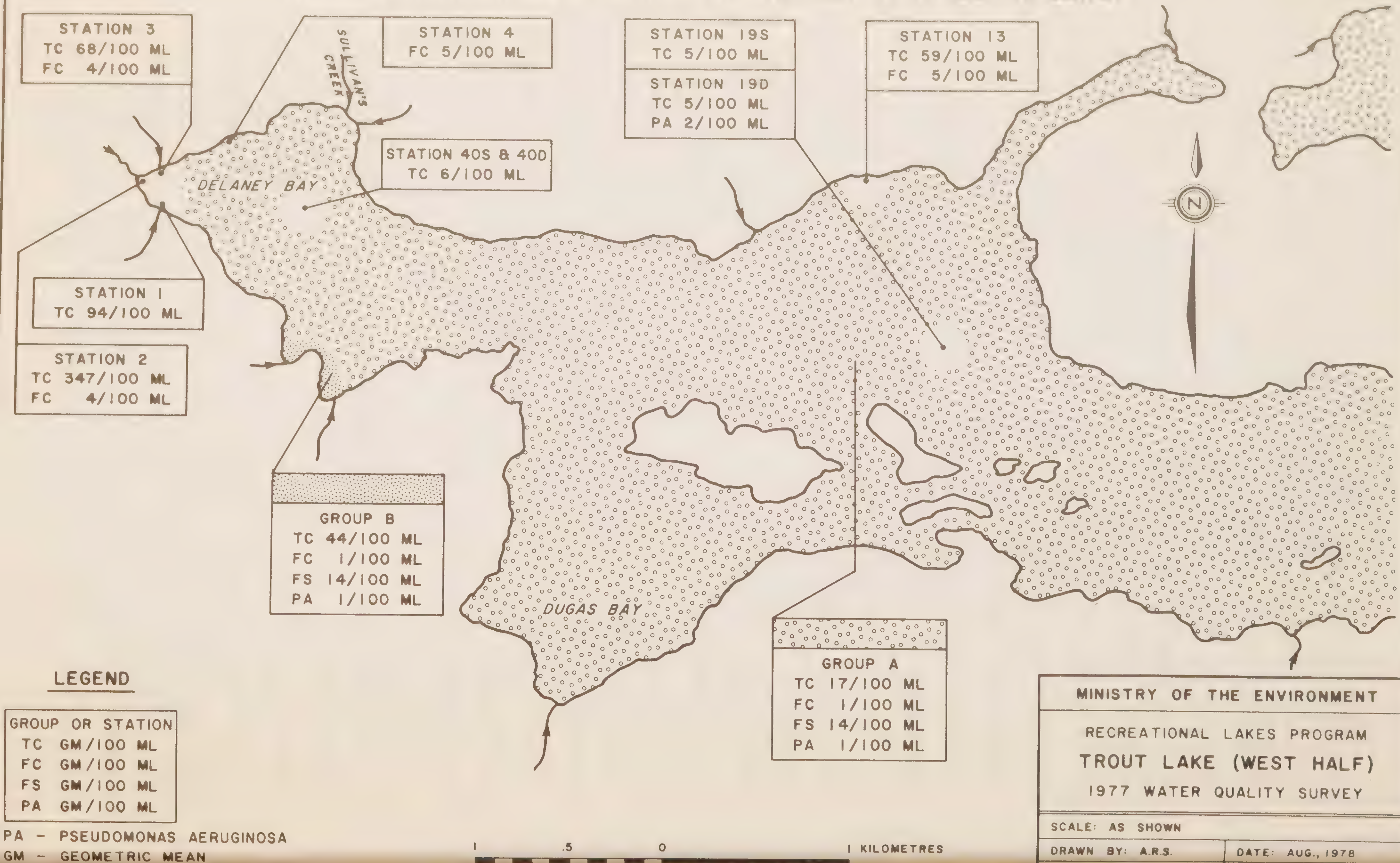
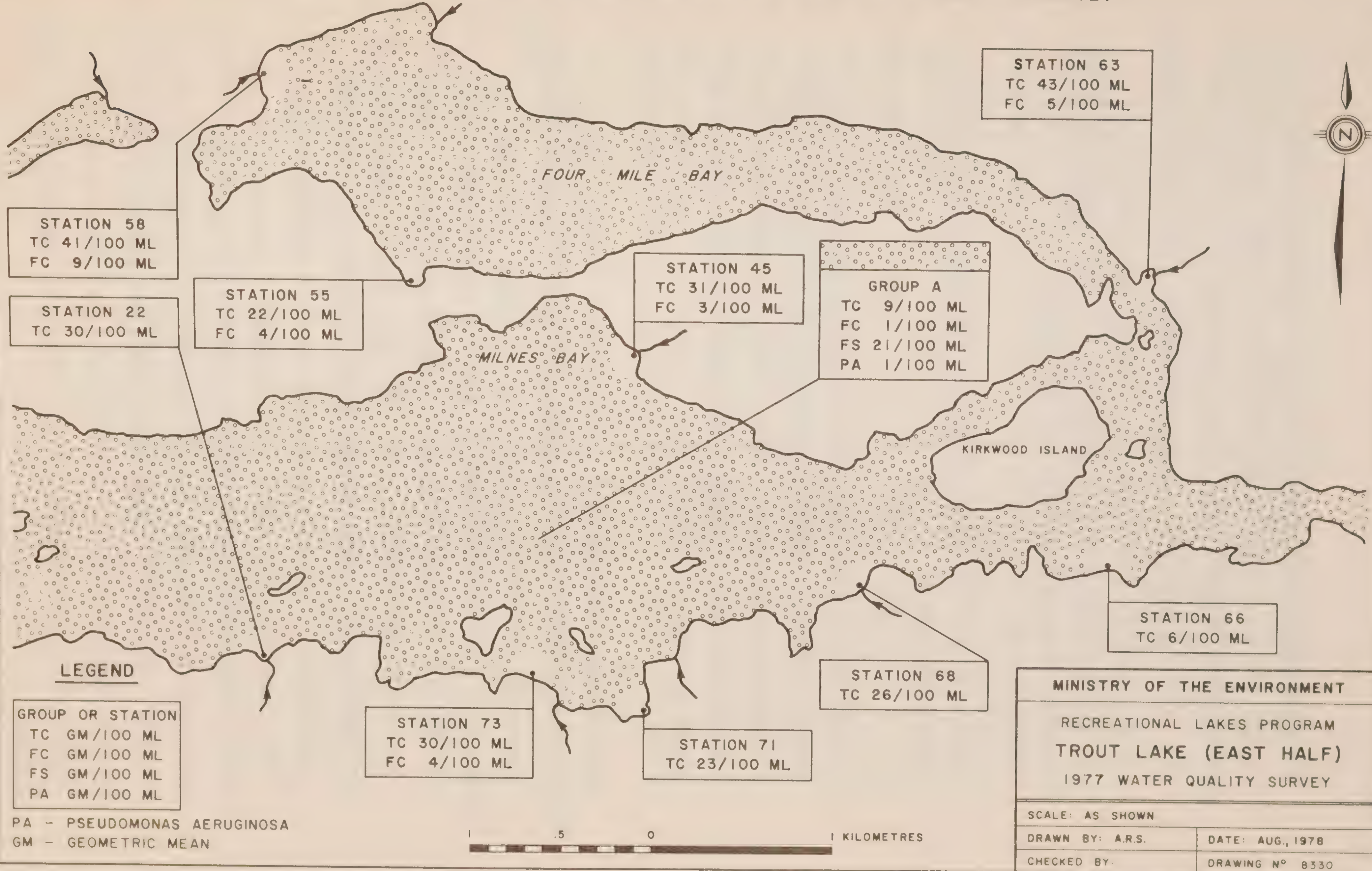


FIGURE 10 - DISTRIBUTION OF BACTERIA FOR THE JULY 19 TO JULY 23 SURVEY



At a cottaged area (station 73) fecal coliform levels were 4 FC per 100 ml. Further east, another cottaged area (station 66) had low total coliform concentrations of 6 TC per 100 ml. In Four Mile Bay, elevated coliform levels were detected at the mouths of two inflowing streams (stations 63 and 58) and a cottaged area (station 55), where densities ranged from 22 to 43 TC and 4 to 9 FC per 100 ml.

The geometric mean density for the heterotrophic bacteria was 373 HB per ml.

The bacterial levels for the overlapping stations 21, 22 and 23 were not significantly different between the first and second halves of the surveys, thereby indicating that similar bacterial concentrations were found throughout the survey period.

The bacterial densities in the main body of water were similar for both spring and summer surveys, although, fecal streptococcus densities did increase during the summer period. In July the elevated total coliform levels found in the area of Sullivan's Creek in June had dissipated and the area in the northwest part of Four Mile Bay had been reduced to one station located at the mouth of the inflowing stream (Station 59). The July coliform concentrations were greater there than those detected in the spring. The densities were still well within the Microbiological Recreational Use Criteria and therefore did not appear to indicate a health hazard. In July the small area where two inflowing streams on the southwest shore enter the lake (stations 36 and 37), low total coliform densities indicating minimal pollution were found.

During the July survey several localized areas, the marina (station 4), some cottaged areas (stations 13, 73 and 55) and a few inflowing streams (stations 45 and 63) had increased fecal coliform concentrations.

These bacterial densities were low; and so, there was no need for concern. During the two surveys, elevated bacterial densities were found at several inflowing streams (stations 2, 3 and 22) in the main part of the lake and station 58 in Four Mile Bay which was mentioned earlier. The inflowing streams in the northwest part of the lake (stations 2 and 3) had increased coliform densities in July and the inflowing stream located at the mid southern part of the lake, station 22, had total coliform densities that were similar to those found in June. However, all these bacterial concentrations were relatively low which indicated that the waters in these areas were safe for recreational users.

Suitability of Surface Waters as a Private Drinking Water Source

While the population densities of bacteria were within the range expected and normally found in good quality surface waters, the presence of total coliform, fecal coliform and fecal streptococcus groups renders untreated water unsuitable for human consumption.

Homeowners who use the water from the lake directly, are advised to apply appropriate treatment methods (chlorination) to ensure that water used for drinking is bacteriologically safe.

Testing of Drinking Water Samples

Bacterial densities in the lake water at the intake to the water treatment plant were so low that they were not detected by regular membrane filtration procedures. The drinking water supply did contain some bacteria which were detected by the P-A test, much less frequently from the treated water than from the raw water supply (Table 1). The positive isolations of *Clostridium perfringens*, a long lived and persistent indicator bacterium, from the raw and treated water indicated that some fecal bacteria (not of recent origin) found their way into the water supply. The hazard to health was not high but the potential was present. Continued water treatment and further water quality monitoring are recommended.

Number of Samples in which Indicator Bacteria were Present

Table 1

		Fecal Coli-form	Fecal Strepto-coccus	*Pseudomonas aeruginosa*	*Clostridium perfringens*
Lake Water at Intake	June	0*	0	0	4
	July	1	5	0	5
Raw Water Before Treatment	June	0	0	0	5
	July	0	5	0	2
Treated Water	June	0	0	0	1
	July	0	1	0	1

* Total number of samples per set was five (e.g.: 0 of 5)

TROUT LAKE PHOSPHORUS BUDGET

In the Northeastern Region of the Ministry of the Environment, a phosphorus budget approach is being used as an indication of water quality and as a prediction of water quality changes likely to occur following the development of shoreline housing units.

The rationale and input parameters used in the calculation of the phosphorus budget and the projection of the effects of additional shoreline development are shown in the Appendix.

It has been found (Dillon, 1974) that the trophic status (degree of nutrient enrichment) of lakes can be related to the amount of phosphorus present at spring turnover when the water is completely mixed.

General categories or levels of water quality based on the quantity of total phosphorus present in the spring have been identified.

Level 1 (Excellent)

Springtime phosphorus concentrations between 0 and 9.9 mg/m^3. Such lakes are primarily suited for body contact recreation because of extremely clear water and low order of biological productivity. In deep lakes, dissolved oxygen concentrations in hypolimnetic (bottom) waters will remain favourable for the support of cold water fish species like lake trout.

Level 2 (Good)

Springtime phosphorus concentrations between 10 and 18.5 mg/m^3. Lakes in this category are suitable for water-based recreation but the preservation of cold water fisheries is not guaranteed. Level 2 lakes are less clear with moderate primary biological activity.

Level 3 (Fair)

Springtime phosphorus concentrations between 18.5 and 29.9 mg/m^3. Level 3 lakes are characterized by reduced suitability for body contact aquatic recreation because of high concentrations of suspended algae and associated nuisances like odours and turbid water. Oxygen depletion in deep basins will be common and there is danger of winterkill of fish in shallow lakes.

Level 4 (Poor)

Springtime phosphorus concentrations above 30 mg/m^3. Such lakes are suitable only for warm water fisheries and there is considerable danger of winterkill of fish. Other recreational uses like swimming, boating and water skiing are extremely unpleasant.

The springtime phosphorus concentrations of Trout Lake and Four Mile Bay were determined at four locations in May 1976 (Figure 11). Total phosphorus in Trout Lake proper ranged from 9 to 10 mg/m^3 and averaged 9.7 mg/m^3 while a single reading of 8 mg/m^3 was obtained in Four Mile Bay.

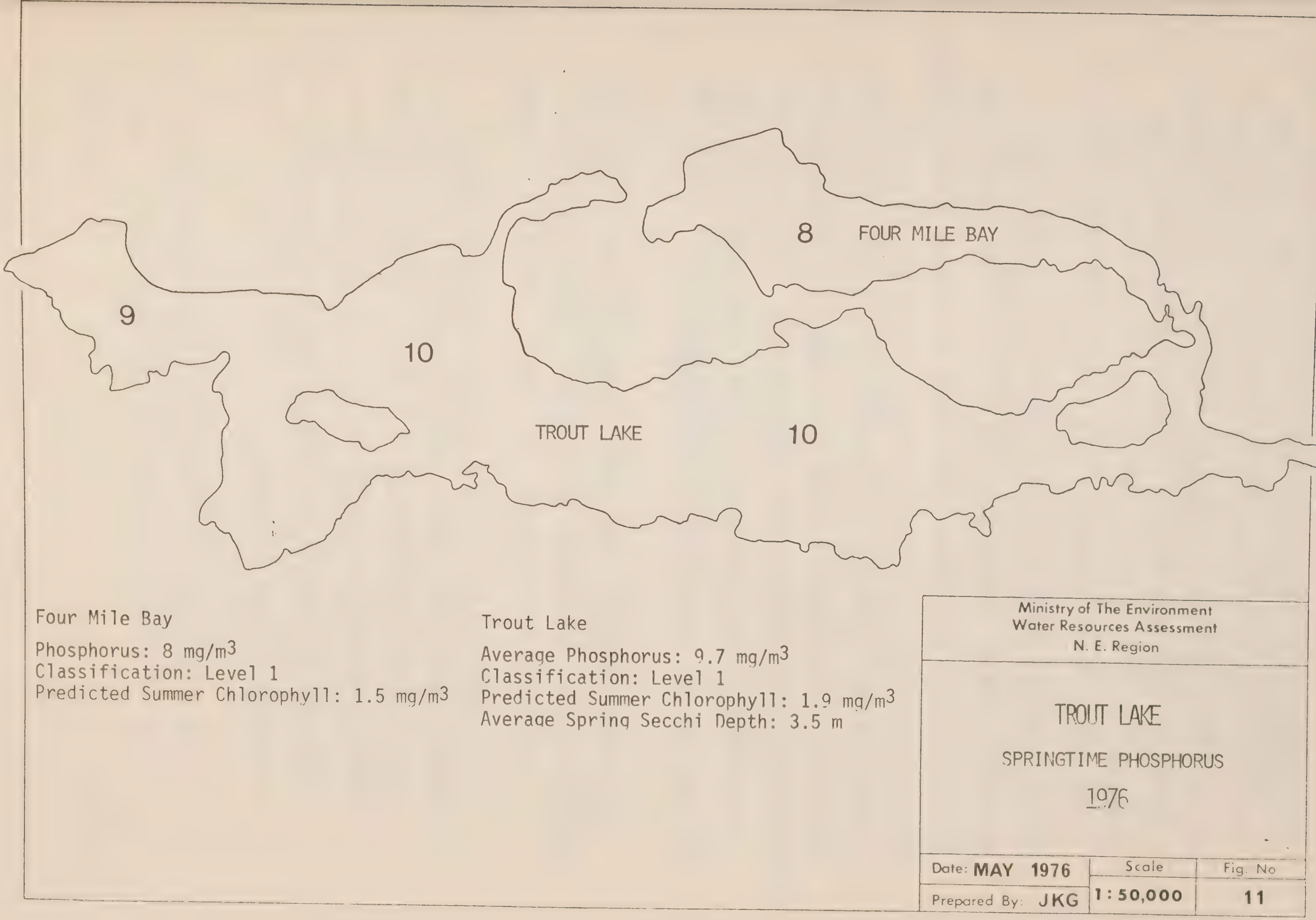
Both Trout Lake and Four Mile Bay were classified within the Level 1 or excellent category of water quality; however, both water bodies were approaching the upper phosphorus limits of their categories.

Results and classification are generally in agreement with observations during the summertime water chemistry survey, but, some discrepancies were found.

The average chlorophyll a concentration is related to springtime phosphorus by the following equation:

$$\log_{10} [\text{Chl } \underline{a}] = 1.45 \log_{10} [P] - 1.14$$

Chlorophyll a concentrations in 1977 were lower than predicted by the spring phosphorus levels (Figure 11), however, analytical difficulties were thought to have been responsible for the depressed values observed.


9
10
8
FOUR MILE BAY
TROUT LAKE
10
Four Mile Bay
Phosphorus: 8 mg/m3
Classification: Level 1
Predicted Summer Chlorophyll: 1.5 mg/m3
Trout Lake
Average Phosphorus: 9.7 mg/m3
Classification: Level 1
Predicted Summer Chlorophyll: 1.9 mg/m3
Average Spring Secchi Depth: 3.5 m
Ministry of The Environment
Water Resources Assessment
N. E. Region
TROUT LAKE
SPRINGTIME PHOSPHORUS
1976
Date: MAY 1976
Prepared By: JKG
Scale
1:50,000
Fig. No
11

The chlorophyll a concentrations in the main body of Trout Lake in 1975 (2.6 ug/L) were slightly higher than predicted by the spring phosphorus concentrations while the chlorophyll a levels in Four Mile Bay (4.3 ug/L) were much higher than predicted.

Since spring phosphorus concentrations are a product of phosphorus import through precipitation, surface runoff, and land use in the watershed, the in-lake phosphorus concentrations can be expected to vary from year to year in relation to varying climatic factors. Evaluation of the water quality parameters investigated during this survey indicates that the phosphorus classification for Trout Lake should fall approximately within the upper range of the Level 1 category as shown by the spring phosphorus samples.

In the calculation of a phosphorus budget for Trout Lake and Four Mile Bay, two sources of phosphorus were considered:

1) The phosphorus originating from the drainage basin i.e. natural load from runoff and precipitation. An export factor of 4.4 $mg/m^2/yr$ was used for Trout Lake and 3.9 $mg/m^2/yr$ for Four Mile Bay, because of the igneous character of the bedrock geology and stream drainage densities of each watershed.

2) The artificial phosphorus input from septic tank tile fields of existing development. Because definitive information regarding the percentage of permanent versus seasonal residences was not available, a count of plowed driveways was undertaken in March 1979. It was found that 336 of the estimated 510 units on Trout Lake proper were year-round residential and that 53 of the 154 units on Four Mile Bay were also used year-round.

For the estimation of septic tank phosphorus inputs it was assumed that all phosphorus present in human waste finds its way to the lake. This amounts to approximately 800 gms/yr/person. For this reason, estimates of the effect of additional development are <u>maximum effect</u> estimates.

Phosphorus budget and development capacities for Trout Lake and Four Mile Bay were computed on an Hewlett Packard 9825A system. Calculator outputs are shown in the Appendix.

Based on theoretical phosphorus supply estimates, a springtime phosphorus concentration of 11.6 mg/m^3 was predicted for Trout Lake proper and 10.2 mg/m^3 for Four Mile Bay. These did not compare favourably with the measured values of 9.7 and 8.0 mg/m^3 respectively.

The difference between the theoretical and actual spring phosphorus values may be explained in a number of ways including:

1) overestimating of natural phosphorus loading via precipitatio and surface runoff

2) overestimation of the number of year-round residential units

3) overestimation of phosphorus inputs from artificial sources

The more reliable, measured spring phosphorus values were used as a base for the calculation of development capacity.

For Trout Lake, a development capacity of 68 cottages or 13 permanent dwellings was determined if Level 1 conditions were to be maintained.

On the basis of the 8 mg/m^3 spring phosphorus concentration detected in Four Mile Bay the additional development capacity was calculated as 202 seasonal and 39 permanent units if a Level 1 order of water quality was desired.

Since the main body of Trout Lake supports a viable cold water fishery and is the source of the city water supply, a high order of water quality should be maintained. Deterioration beyond a Level 1 classification should be avoided.

Because a relatively low development capacity of 68 cottages or 13 permanent dwellings was determined for Trout Lake proper, any additional shoreline development should be carefully evaluated by the local planning agencies in consultation with District staff of the Ministry of the Environment.

Because of the 5:1 ratio of phosphorus supply for permanent versus seasonal residences, it should be realized that conversion of each existing seasonal unit to a permanent residence will reduce the cottage development capacity by 5 units. In addition, the number of vacant lots presently existing has not been included in the calculation of the development capacity nor have development reserves been allocated to the vacant lots.

SUMMARY WATER QUALITY STATUS

The general chemical water quality of Trout Lake was excellent in 1977 although problem areas were discovered.

The main body of the lake contained higher concentrations of dissolved substances than did Four Mile Bay. Chlorides, which likely originate from use of road de-icing salt were significantly higher in Trout Lake proper. Other chemical parameters were present in low to moderate concentrations.

The values of pH remained within the biologically favourable 6.5 to 8.5 range while alkalinity, buffering capacity against inputs of acid, was fair.

Temperature stratification (separation into warm surface and cold deep water layers) was apparent in all deep basins. Vertical dissolved oxygen distribution profiles revealed the existence of near-orthograde or highly favourable oxygen conditions for the support of cold water fisheries.

Concentrations of metallic ions in Trout Lake were very low except for zinc which was found in moderate quantities.

Although most of the incoming streams carried higher loads of dissolved substances than their receiving basins, they appeared to have little effect on receiving water quality. Nutrient inputs from the inflows were not considered to be significant.

Very high concentrations of the biologically toxic heavy

metal, zinc, were detected in Hogan Creek. The zinc originated as runoff and leachate from the site of a 1970 metal concentrate spill along a line of the Ontario Northland Railway (O.N.R.). Biological and chemical monitoring of Hogan Creek following clean-up operations completed in 1978 (see Appendix p 54) have shown improved water quality near the spill site; however, downstream zinc concentrations have remained high. Additional investigation into the continuing source of zinc to the lower reaches of Hogan Creek is scheduled for 1979.

Four Mile Creek also contained elevated zinc concentrations with potential for inhibition of biological communities. Investigation into zinc concentrations in Four Mile Creek and the health of aquatic biota is warranted and will be undertaken during 1979.

Although both Hogan and Four Mile Creeks contributed zinc to Lounsbury and Four Mile Bays, the concentrations found in the Bays, approximately 0.07 mg/L, were well below the drinking water objective of 5 mg/L and had no effect on the quality of the water supply.

Water transparency or clarity was excellent in the main body of Trout Lake while in Four Mile Bay moderate transparency readings were found. Primary biological productivity (algae) was low to moderate.

The effect of present development on the bacteriological water quality of Trout Lake has not been great. For instance, low fecal coliform densities were detected at the marina and

several cottaged areas along with some inflowing streams, however, these densities did not appear to affect the good bacteriological water quality of the main body of lake-water. Furthermore, the bacterial levels in the water column were not greater than those generally found in undeveloped lakes.

Because total coliform, fecal coliform and fecal streptococcus groups were isolated from the surface waters, the use of untreated water for private supply is not recommended. With respect to the City of North Bay municipal water supply low levels of fecal indicator bacteria (*C. perfringens*) were isolated from raw and treated drinking water at the treatment plant and it was concluded that disinfection of water should continue and that regular water quality monitoring should be maintained.

A theoretical phosphorus budget and development capacity based on the ability of Trout Lake and Four Mile Bay to assimilate additional nutrient loading revealed that the actual phosphorus concentrations measured were not similar to theoretically expected values. Because it is desirable to maintain a Level 1 order of water quality in both major basins of Trout Lake additional development on Trout Lake proper should be evaluated very carefully. Addition of 68 cottages or 13 permanent dwellings has the potential to produce a change in water quality classification in Trout Lake. Four Mile Bay has a larger development potential as 202 cottages or 39 permanent dwellings are required for a shift to the next class of water quality.

BIBLIOGRAPHY

1. Dillon, P.J., 1974. A Manual for Calculating the Capacity of a Lake for Development. Ontario Ministry of the Environment.

2. Hendry, G.S., 1977. Relationships Between Bacterial Levels and Other Characteristics of Recreational Lakes in the District of Muskoka. Part 1-Aerobic Heterotrophic Bacteria. Part 2-Total Coliform Bacteria M.O.E. p. 63

3. Levin, M.A. and Cabelli, V.J., 1972. Membrane Filter Technique for Enumeration of *Pseudomonas aeruginosa* Appl. Micro. 24, 6, 664-870.

4. Ministry of the Environment, 1973. Report on the Water Quality in Jerry Lake, p. 37

5. ______________________________, 1976. The Enumeration of Pollution Indicator Bacteria, p. 24

6. ______________________________, 1976. The Presence-Absence Procedure, p. 28

7. ______________________________, 1978. Water Management. Goals, Policies, Objectives and Implementation Procedures.

APPENDIX

CONTENTS

Table A

CHEMICAL WATER QUALITY OF TROUT LAKE JUNE 10, 1977

PARAMETER	S Surface / B Bottom	SAMPLING STATION									
		1	2	3	4	5	6	7	8	9	10
Hardness	S	22	22	22	22	22	21	21	21	16	16
	B	22	22	22	22	22	22	22	22	16	16
Alkalinity	S	12	11	11	12	11	11	11	11	8	8
	B	12	11	11	12	11	11	11	11	8	7
pH	S	7.2	7.2	7.1	7.1	7.1	7.1	7.1	7.1	6.9	6.9
	B	7.1	7.0	6.7	6.9	6.9	6.9	6.9	6.8	6.6	6.6
Conductivity	S	83	83	83	83	83	82	82	78	55	55
	B	84	83	82	83	82	82	82	78	55	54
Colour	S	10	15	5	5	5	5	10	10	10	10
	B	10	10	10	10	10	10	10	10	15	15
Total Phosphorus	S	<.001	.003	.005	.005	.002	.003	.003	.003	.003	.003
	B	.004	.008	.005	.005	.003	.004	.004	.005	.003	.003
Total Kjeldahl Nitrogen	S	.17	.18	.16	.18	.16	.16	.16	.18	.17	.16
	B	.18	.19	.19	.18	.17	.18	.17	.23	.17	.16
Ammonia	S	.012	.012	.016	.016	.016	.016	.016	.018	.016	.014
	B	.016	.018	.014	.016	.012	.012	.012	.026	.018	.018
Nitrite	S	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002
	B	.002	.002	.002	.002	.002	.002	.002	.002	.001	.001
Nitrate	S	.208	.213	.228	.228	.233	.238	.228	.208	.218	.228
	B	.228	.248	.273	.228	.268	.263	.268	.238	.254	.254

Table A continued...

PARAMETER	S Surface / B Bottom	SAMPLING STATION 1	2	3	4	5	6	7	8	9	10
Organic Carbon	S	5	7	5	5	5	5	5	6	6	5
	B	5	7	6	6	5	6	5	7	6	5
Inorganic Carbon	S	3	2	3	3	3	2	2	2	1	1
	B	2	2	2	2	2	2	2	2	1	2
Calcium	S	6.2	6.0	6.0	6.0	6.0	5.8	5.8	5.6	4.4	4.4
	B	6.0	6.2	6.2	6.0	6.2	6.2	6.2	6.0	4.4	4.4
Magnesium	S	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.6	1.1	1.1
	B	1.8	1.7	1.7	1.8	1.7	1.7	1.7	1.7	1.1	1.1
Sulphate	S	11	11	11	11	11	11	11	11	10	10
	B	11	11.5	11.5	11	11.5	11.5	11.5	11	10	10
Chloride	S	8.8	8.6	8.5	8.6	8.3	8.2	8.2	7.6	3.2	3.1
	B	8.9	8.6	8.4	8.6	8.2	8.2	8.3	7.3	3.1	3.1

All concentrations in mg/L except pH, conductivity (umhos/cm) and colour (Hazen Units)

Table B

CHEMICAL WATER QUALITY OF TROUT LAKE JULY 19, 1977

S Surface
B Bottom

PARAMETER		SAMPLING STATION 1	2	3	4	5	6	7	8	9	10
Hardness	S	21	21	21	21	21	21	21	20	16	16
	B	21	21	21	22	21	24	20	21	15	16
Alkalinity	S	12	12	11	12	12	12	11	12	8	8
	B	11	12	14	13	11	11	11	11	8	8
pH	S	7.3	7.2	7.2	6.6	7.9	6.9	7.9	7.4	7.1	7.1
	B	6.8	7.2	6.8	7.1	7.2	7.2	6.7	7.3	7.4	6.6
Conductivity	S	83	82	83	83	82	82	82	78	56	56
	B	84	83	83	86	82	82	82	80	55	55
Colour	S	15	15	15	15	15	15	15	10	20	20
	B	15	20	10	15	15	15	10	10	20	20
Total Phosphorus	S	.004	.004	.004	.004	.004	.004	.003	.007	.004	.004
	B	.004	.004	.002	.008	.002	.010	.003	.005	.008	.002
Total Kjeldahl Nitrogen	S	.24	.23	.23	.25	.22	.21	.21	.22	.30	.28
	B	.19	.25	.19	.23	.18	.20	.19	.23	.31	.22
Ammonia	S	.004	.008	.008	.004	.004	.004	.004	.030	.006	.014
	B	.010	.004	.012	.038	.006	.012	.006	.004	.020	.022

Table B continued ...

PARAMETER	S Surface / B Bottom	SAMPLING STATION 1	2	3	4	5	6	7	8	9	10
Nitrite	S	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002
	B	.002	.002	.001	.003	.001	.002	.001	.002	.002	.001
Nitrate	S	.118	.103	.123	.123	.123	.103	.098	.153	.093	.108
	B	.228	.128	.229	.172	.219	.198	.214	.088	.148	.219
Organic Carbon	S	5	2	5	4	4	4	5	4	6	5
	B	5	5	4	3	4	4	4	4	5	4
Inorganic Carbon	S	2	6	2	2	2	2	2	3	1	1
	B	2	2	2	3	2	2	2	2	1	2
Calcium	S	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.4	4.6	4.6
	B	5.6	5.6	5.6	5.8	5.6	7.0	5.4	5.6	4.4	4.4
Magnesium	S	1.6	1.8	1.8	1.8	1.8	1.7	1.7	1.6	1.2	1.2
	B	1.8	1.8	1.8	1.8	1.7	1.7	1.7	1.7	1.0	1.2
Sulphate	S	11	11	11	11	11	11	12	11	10.5	10
	B	11	11	11	11	12	11	12	11	10	10
Chloride	S	8.4	8.4	8.3	8.4	8.3	8.3	8.2	7.1	3.4	3.3
	B	8.2	8.4	8.2	8.4	8.1	8.1	8.1	7.8	3.2	3.0
Iron	S	.03	.05	.02	.02	.02	.03	.02	.03	.03	.04
	B	.03	.06	.05	.02	.02	.13	.02	.02	.05	.07

All concentrations in mg/L except pH, conductivity (umhos/cm) and colour (Hazen Units)

Table C

CHEMICAL WATER QUALITY OF TROUT LAKE SEPTEMBER 16, 1977

PARAMETER	S Surface / B Bottom	SAMPLING STATION									
		1	2	3	4	5	6	7	8	9	10
Alkalinity	S	11	11	11	11	11	11	11	11	8	8
	B	12	11	11	12	11	11	11	11	8	7
pH	S	7.1	7.0	7.0	7.0	7.1	7.0	7.0	7.0	6.9	7.0
	B	7.2	7.0	6.5	7.0	6.5	6.5	6.5	6.3	6.4	6.3
Conductivity	S	79	81	81	82	82	80	81	79	54	54
	B	81	81	81	82	81	81	81	78	55	54
Total Phosphorus	S	.002	.003	.004	.006	.018	.006	.004	.009	.005	.004
	B	.006	.004	.004	.008	.011	.004	.009	.006	.005	.004
Total Kjeldahl Nitrogen	S	.24	.24	.21	.30	.28	.31	.28	.28	.27	.29
	B	.26	.24	.23	.31	.24	.18	.25	.24	.27	.24
Ammonia	S	.012	.008	.008	.008	.006	.006	.008	.010	.014	.016
	B	.002	.008	.008	.010	.004	.008	.006	.008	.018	.008
Nitrite	S	.002	.002	.002	.001	.001	.002	.002	.002	.002	.002
	B	.002	.002	<.001	.001	<.001	.001	.001	.001	.001	.001
Nitrate	S	.118	.098	.108	.109	.104	.108	.108	.073	.048	.048
	B	.108	.103	.255	.109	.255	.259	.254	.234	.144	.234
Organic Carbon	S	5	5	6	5	5	5	5	5	6	5
	B	5	4	4	5	3	5	3	4	8	4

Table C continued...

PARAMETER	S Surface B Bottom	SAMPLING STATION									
		1	2	3	4	5	6	7	8	9	10
Inorganic Carbon	S	3	3	3	3	3	3	3	3	2	2
	B	3	3	4	3	4	3	4	4	3	3
Sulphate	S	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	11	11
	B	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.0	11	11
Chloride	S	8.7	8.6	8.6	8.5	8.4	8.3	8.4	7.7	3.4	3.4
	B	8.7	8.5	8.3	8.5	8.2	8.2	8.2	7.2	3.3	3.5
Iron	S	.03	.03	.03	.02	.02	.02	.02	.03	.04	.04
	B	.03	.02	.02	.02	.02	.02	.02	.02	.06	.06

All concentrations in mg/L except pH, conductivity (umhos/cm) and colour (Hazen Units)

CHEMICAL WATER QUALITY OF TROUT LAKE INFLOWING STREAMS JUNE 11, 1977

PARAMETER	ST-1	ST-2	ST-3	ST-4	ST-5	ST-6	ST-7	ST-8	ST-9	ST-10
Free Ammonia	.008	.008	.024	.012	<.002	.074	.018	.024	.042	.026
Total Kjeldahl	.28	.11	.34	.18	.09	.58	.42	.35	.50	.31
Nitrite	.002	.001	.004	.002	.001	.004	.003	.004	.003	.003
Nitrate	.568	.174	.376	.183	.154	.056	.117	.151	.137	.167
Total Phosphorus	.006	.002	.009	.008	.002	.028	.029	.021	.031	.007
Hardness	27	38	28	17	28	17	24	24	33	28
Alkalinity	13	9	15	9	21	12	15	13	21	15
Chloride	15.0	5.9	10.5	3.1	.5	3.1	6.5	8.9	11.5	14.0
pH	7.26	6.75	7.06	7.18	6.71	6.64	6.92	6.99	7.22	7.24
Calcium	7.6	10.4	7.8	4.8	7.6	4.6	6.6	6.6	8.8	7.6
Magnesium	2.05	2.85	2.10	1.15	2.10	1.45	1.90	1.85	2.60	2.10
Sulphate	12.5	4.5	14.0	10.5	13.0	6.5	10.0	11.0	11.0	12.0
Colour	10	10	50	15	10	<70	50	40	40	15
Organic Carbon	5	3	7	7	5	13	9	8	10	7
Inorganic Carbon	3	2	4	2	7	4	4	3	5	4
Conductivity	118	144	104	56	77	49	78	86	112	114

Table E

CHEMICAL WATER QUALITY OF TROUT LAKE INFLOWING STREAMS JULY 19, 1977

PARAMETER	ST-1	ST-2	ST-3	ST-4	ST-5	ST-6	ST-7	ST-8	ST-9	ST-10
Free Ammonia	.004	.008	.012	.006	.002	.016	.018	.036	.014	.006
Total Kjeldahl	.21	.11	.28	.27	.14	.38	.48	.40	.66	.40
Nitrite	.001	.001	.004	.002	.001	.003	.003	.002	.002	.002
Nitrate	.539	.124	.181	.068	.074	.037	.022	.028	<.005	.028
Total Phosphorus	.004	.002	.014	.014	.008	.029	.026	.030	.036	.007
Hardness	27	47	21	15	27	21	25	29	34	31
Alkalinity	14	10	12	8	21	12	17	18	23	18
Chloride	13.0	5.6	6.8	3.4	.4	7.8	6.2	10.5	17.0	17.0
pH	7.53	6,85	7.14	7.25	6.65	6.90	6.79	6.78	7.07	7.16
Conductivity	112	175	80	57	75	76	78	100	124	125
Calcium	7.4	12.6	5.8	4.2	6.8	5.4	6.4	7.6	8.8	8.2
Magnesium	2.10	3.80	1.65	1.15	2.45	2.00	2.25	2.50	3.00	2.45
Sulphate	12.5	60.0	12.5	10.5	12.0	9.5	9.5	11.0	8.5	11.5
Colour	15	15	60	15	15	50	60	40	60	15
Organic Carbon	7	3	7	6	4	8	9	8	11	7
Inorganic Carbon	3	2	2	1	6	2	4	4	5	4
Iron	.10	.18	.58	.09	.08	.49	.70	.83	.75	.08

Table F

METAL CONTENT OF TROUT LAKE JUNE 7, 1977

PARAMETER	SAMPLING STATION					
	1	3	4	6	8	10
Copper	0.02	0.04	0.02	0.03	0.04	0.03
Nickel	0.01	<.01	<0.01	<.01	0.02	<0.01
Lead	<0.01	<.01	<0.01	<0.01	<0.01	<0.01
Zinc	0.06	0.06	0.07	0.06	0.05	0.07
Cadmium	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005

* Concentration in mg/L

Table G

METAL CONTENT OF TROUT LAKE JULY 17, 1977

PARAMETER	STATIONS									
	1	2	3	4	5	6	7	8	9	10
Copper	0.02	0.03	0.04	0.02	0.03	0.04	0.06	0.07	0.06	0.06
Nickel	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Lead	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Zinc	0.04	0.04	0.05	0.06	0.05	0.06	0.07	0.06	0.08	0.08
Cadmium	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Arsenic	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

* Concentrations in mg/L

Table H

METAL CONTENT OF TROUT LAKE INFLOWING STREAMS JUNE 11, 1977

PARAMETER	STATIONS									
	ST-1	ST-2	ST-3	ST-4	ST-5	ST-6	ST-7	ST-8	ST-9	ST-10
Copper	0.04	0.06	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02
Nickel	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Lead	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	0.06	7.6	0.42	0.06	<0.01	0.02	0.05	0.06	0.03	0.04
Cadmium	<0.005	0.02	<.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Arsenic	0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.001	0.001

* Concentrations in mg/L

Table I

METAL CONTENT OF TROUT LAKE INFLOWING STREAMS JULY 17, 1977

PARAMETER	STATIONS									
	ST-1	ST-2	ST-3	ST-4	ST-5	ST-6	ST-7	ST-8	ST-9	ST-10
Copper	0.08	0.06	0.05	0.05	0.04	0.07	0.06	0.04	0.04	0.04
Nickel	<0.02	<.02	<0.02	<0.02	<.02	<0.02	<0.02	<0.02	<0.02	<0.02
Lead	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Zinc	0.06	8.6	0.34	0.06	<0.02	0.03	0.04	0.06	0.04	0.04
Cadmium	<0.005	0.02	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Arsenic	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

* Concentrations in mg/L

TABLE J

CHLOROPHYLL a (ug/L), SECCHI DISC (S.D.) VISIBILITY (m) TROUT LAKE 1977

	STATION 1		STATION 2		STATION 3		STATION 4		STATION 5	
DATE	Chlo. a	Disc	Chlo. a	Disc	Chlo. a	Disc	Chlo. a	Disc	Chlo. a	Disc
June 7	.6	6.5	.1	6.0	.9	6.5	1.2	6.0	.7	6.0
June 11	1.0	7.0	.9	6.5	2.1	7.0	.8	7.0	.7	6.5
July 13	1.7	6.0	2.4	6.0	1.0	5.5	.7	5.0	.5	5.5
July 18	.6	5.5	.8	5.5	1.6	5.5	3.1	5.5	1.0	6.0
July 20	.6	6.5	.9	5.5	.6	6.0	1.2	6.5	1.0	6.5
July 22	.9	7.0	1.0	6.5	1.2	7.0	-	7.0	.2	7.0
Sept. 9	2.3	5.0					1.6	5.0		

NOTE: * Chlo. - Chlorophyll

TABLE J (cont'd)

CHLOROPHYLL a (ug/L), SECCHI DISC (S.D.) VISIBILITY (m) TROUT LAKE 1977

DATE	STATION 6		STATION 7		STATION 8		STATION 9		STATION 10	
	Chlo. a	Disc	Chlo. a	Disc	Chlo. a	Disc	Chlo. a	Disc	Chlo. a	Disc
June 7	.1	6.0	.5	6.0	.1	6.0	.1	5.5	.1	5.5
June 11	.9	6.5	.8	6.5	.9	6.5	.6	6.0	1.0	6.0
July 13	.7	6.0	.6	5.5	.7	5.0	.6	4.0	.7	4.0
July 18	1.6	6.0	2.1	5.5	1.8	5.5	1.1	4.0	1.2	4.0
July 20	.9	6.5	1.2	6.5	2.0	6.5	1.3	4.5	1.7	4.5
July 22	.3	7.0	1.2	7.5	1.1	6.5	.4	4.5	.6	4.5
Sept. 9	2.0	5.0					1.6	-		

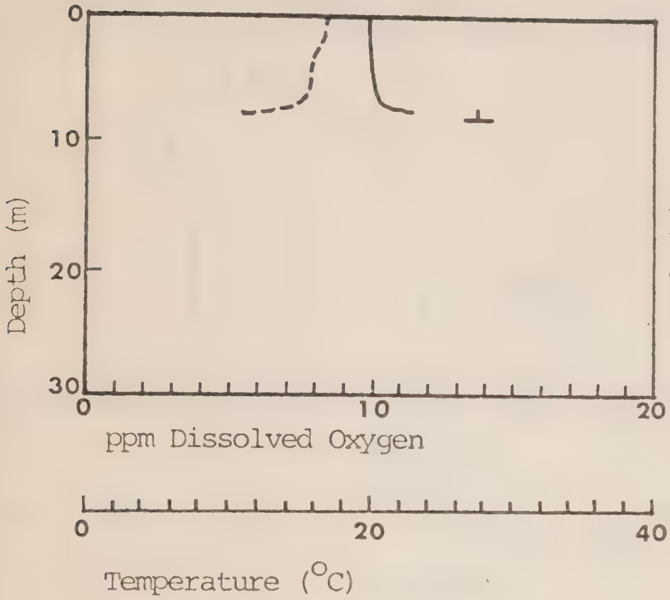
NOTE: * Chlo. - Chlorophyll

Dissolved Oxygen - Temperature Profiles

Trout Lake

June 10 1977

Station 1



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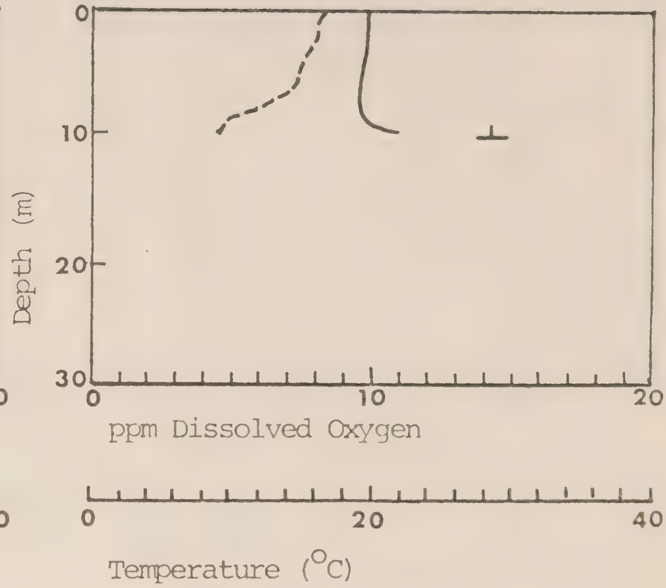

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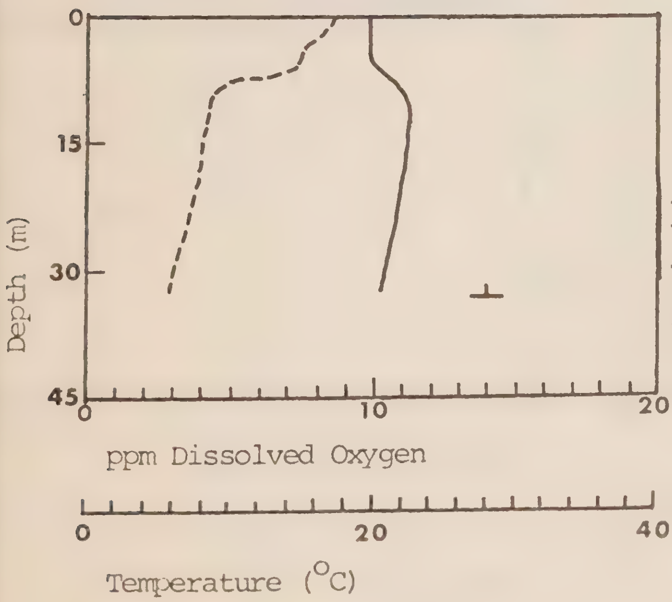

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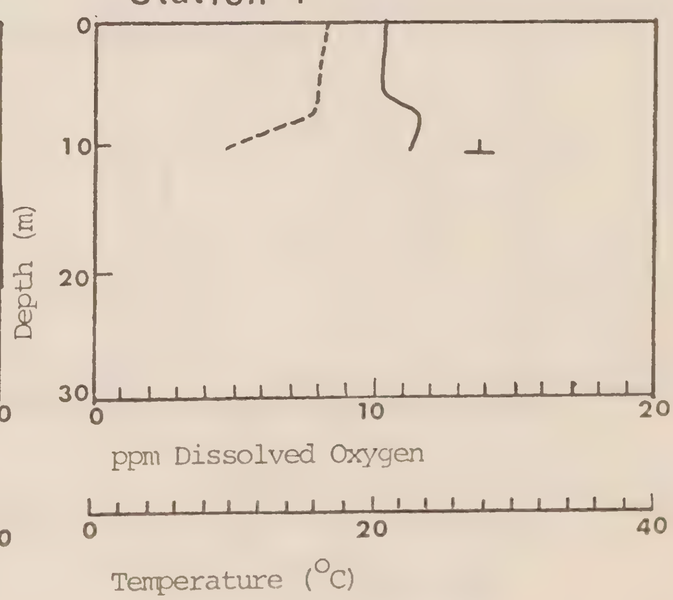


Dissolved Oxygen Curve

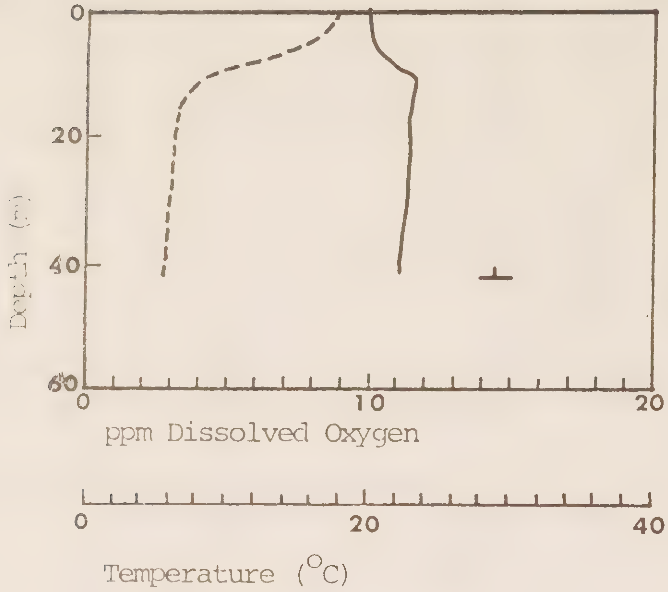
Temperature Curve

Lake Bottom

Dissolved Oxygen - Temperature Profiles

June 10

Station 5



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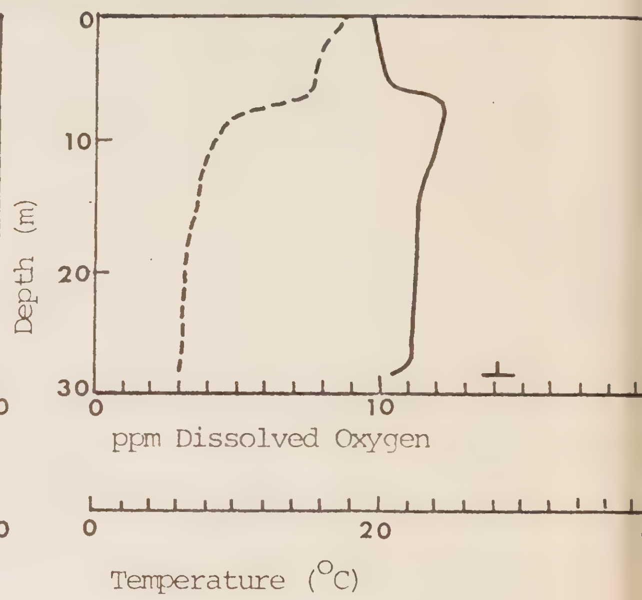

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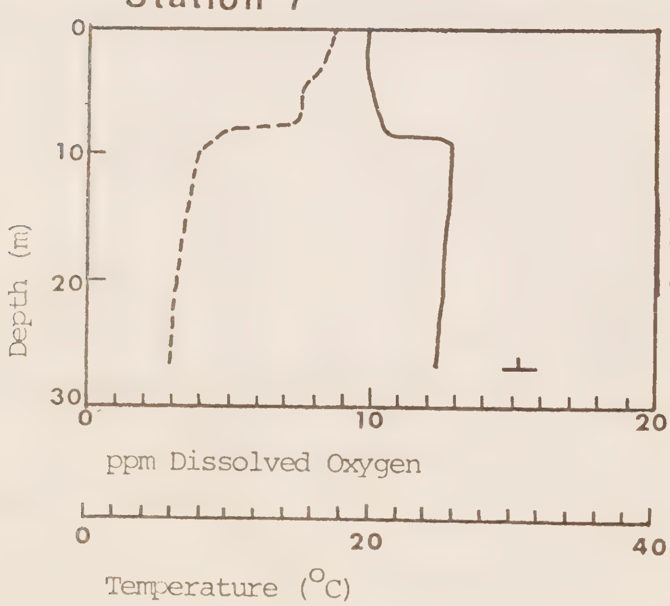
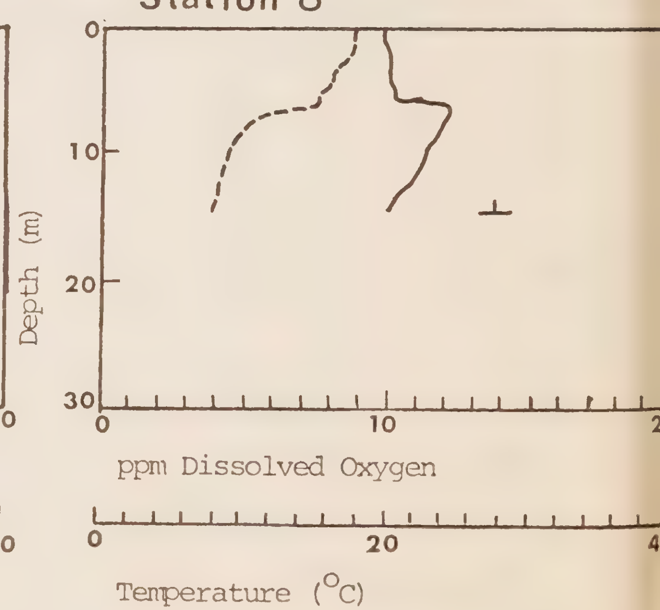


Station 8



——— Dissolved Oxygen Curve

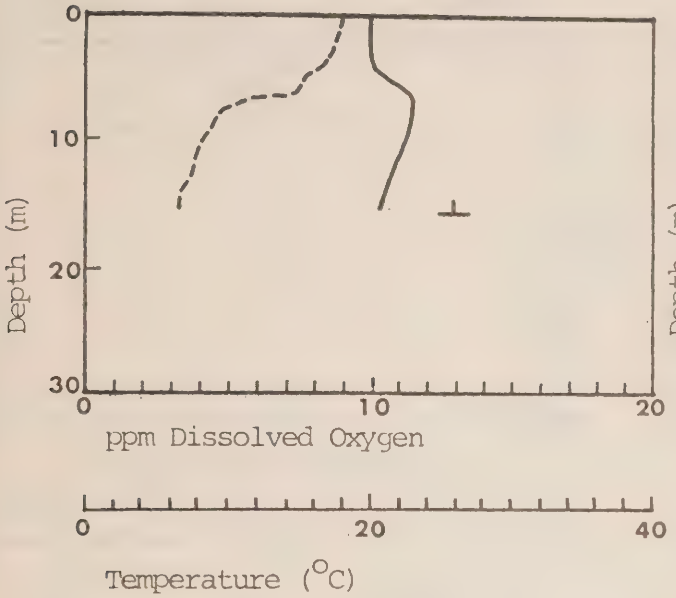
- - - - Temperature Curve

⊥ Lake Bottom

Dissolved Oxygen - Temperature Profiles

June 10

Station 9



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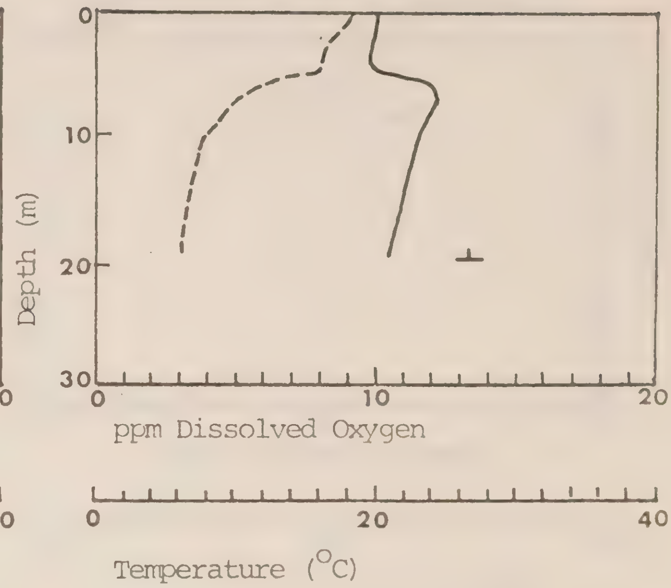

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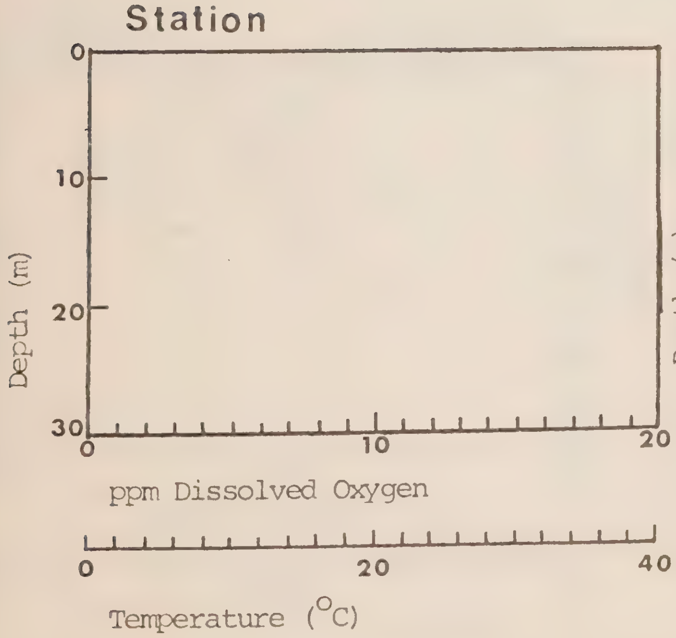

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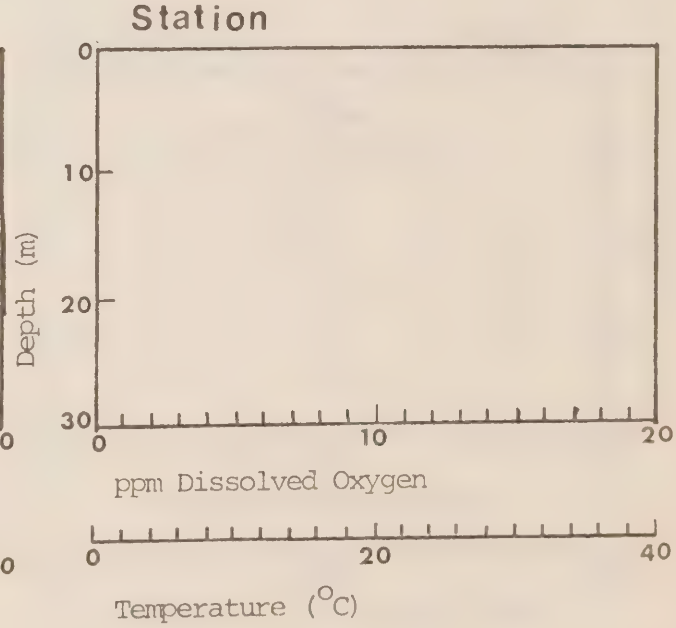


——— Dissolved Oxygen Curve

- - - - Temperature Curve

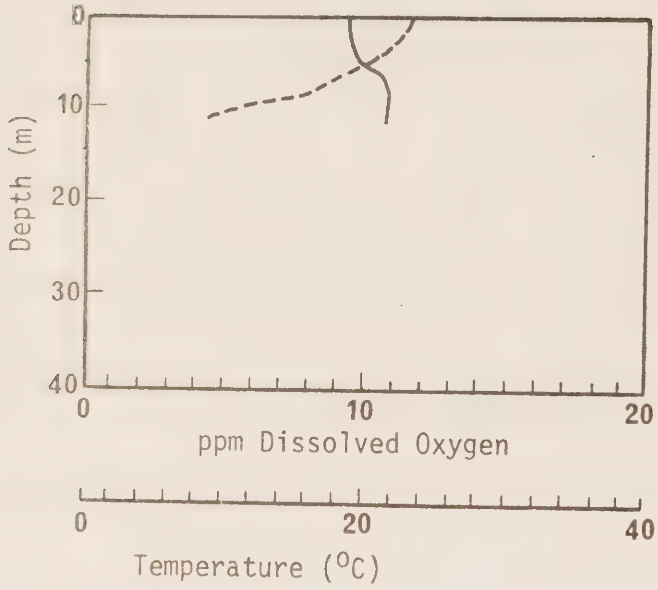
⊥ Lake Bottom

Dissolved Oxygen - Temperature Profiles

Trout Lake

July 19 1977

Station 1



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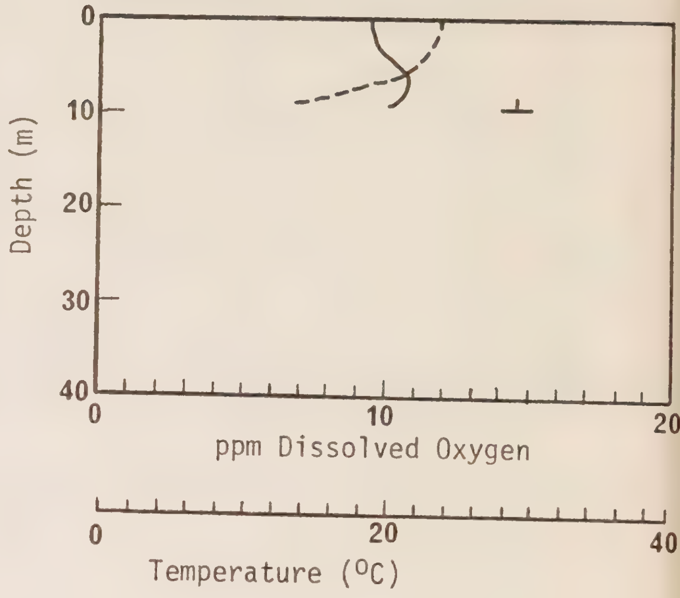

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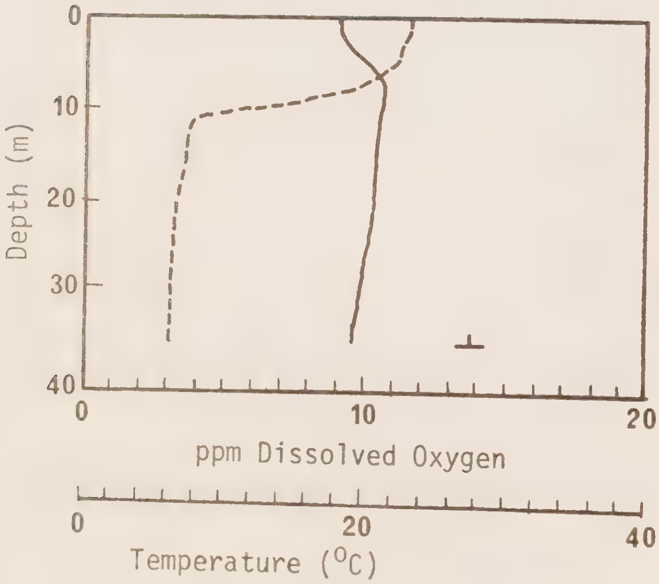

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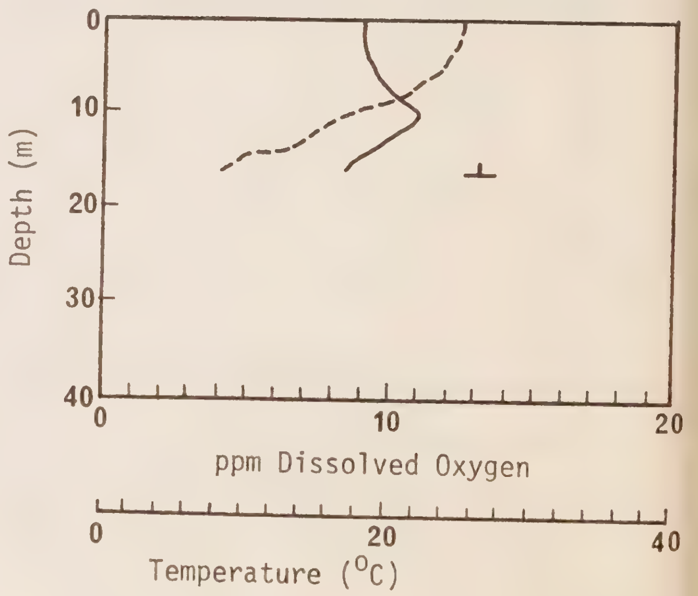


——— Dissolved Oxygen Curve

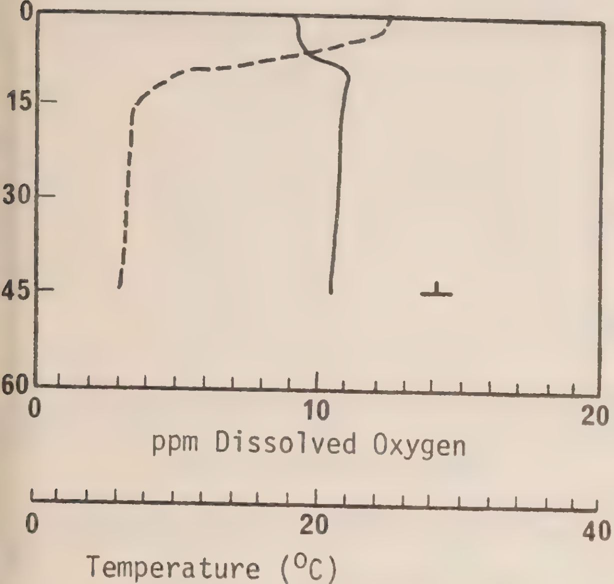
------ Temperature Curve

⊥ Lake Bottom

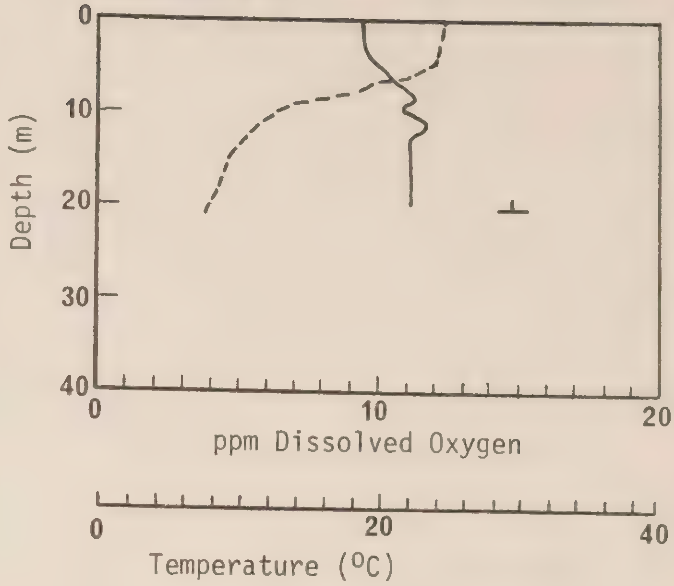
Dissolved Oxygen - Temperature Profiles

July 19

Station 5



Station 6



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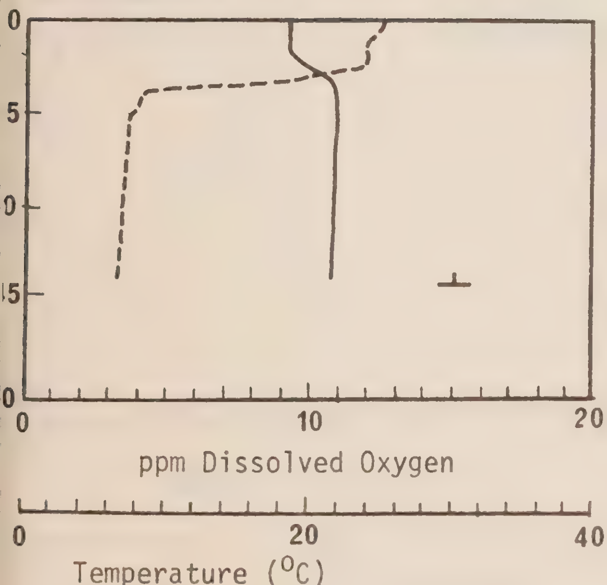
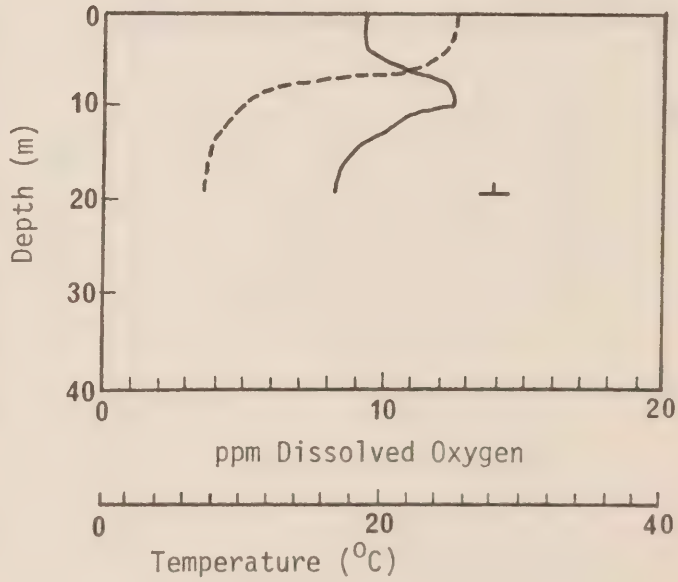


Station 8



Dissolved Oxygen Curve

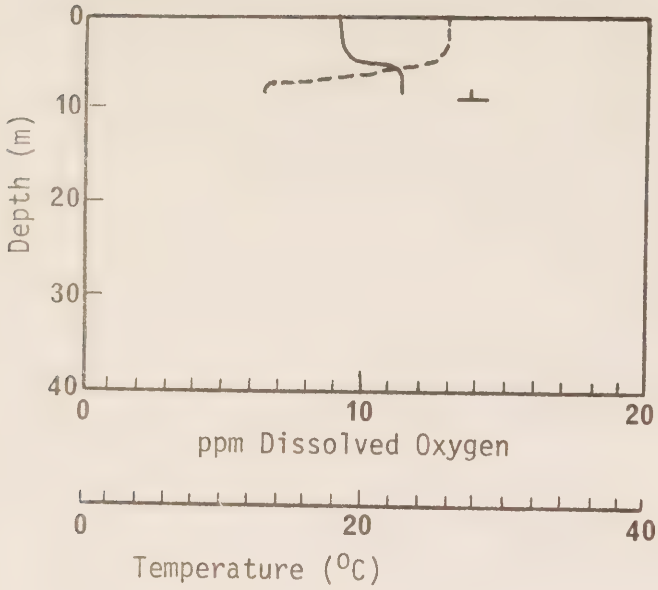
Temperature Curve

Lake Bottom

Dissolved Oxygen - Temperature Profiles

July 19

Station 9



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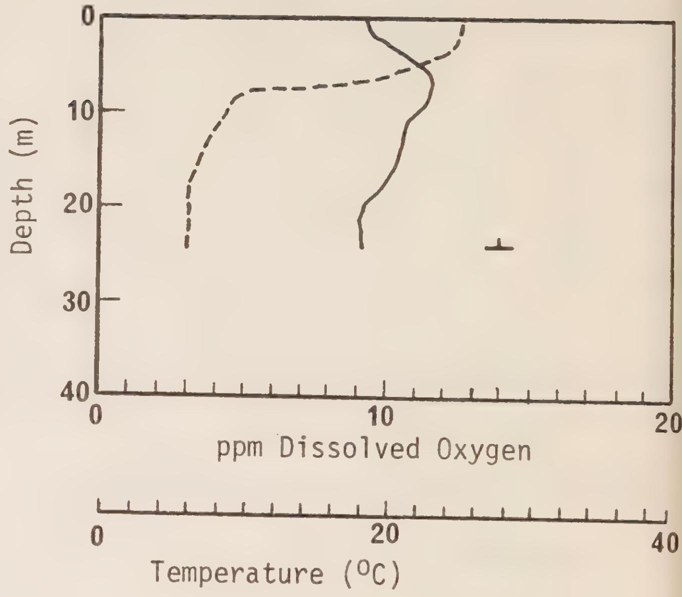

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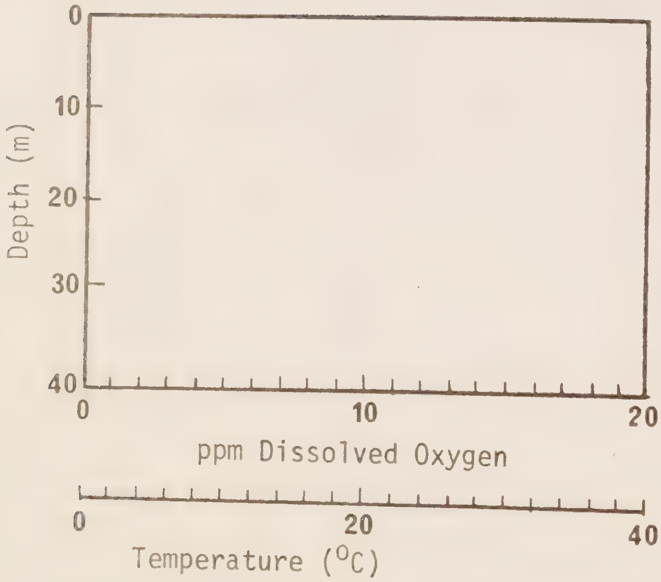

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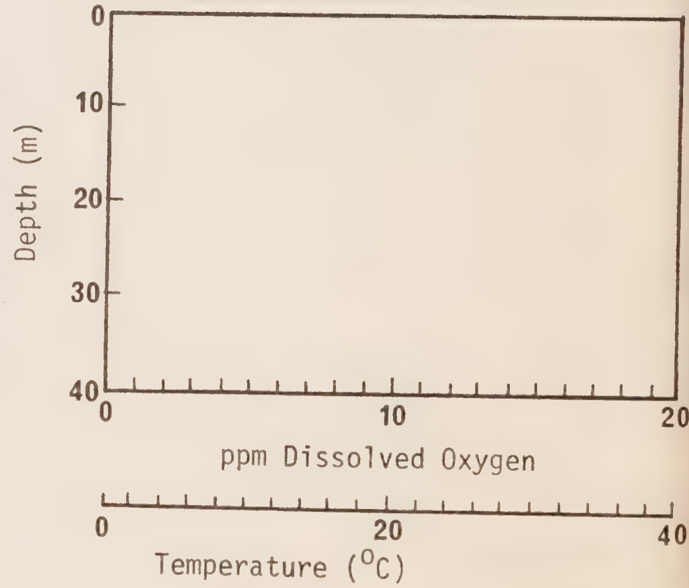


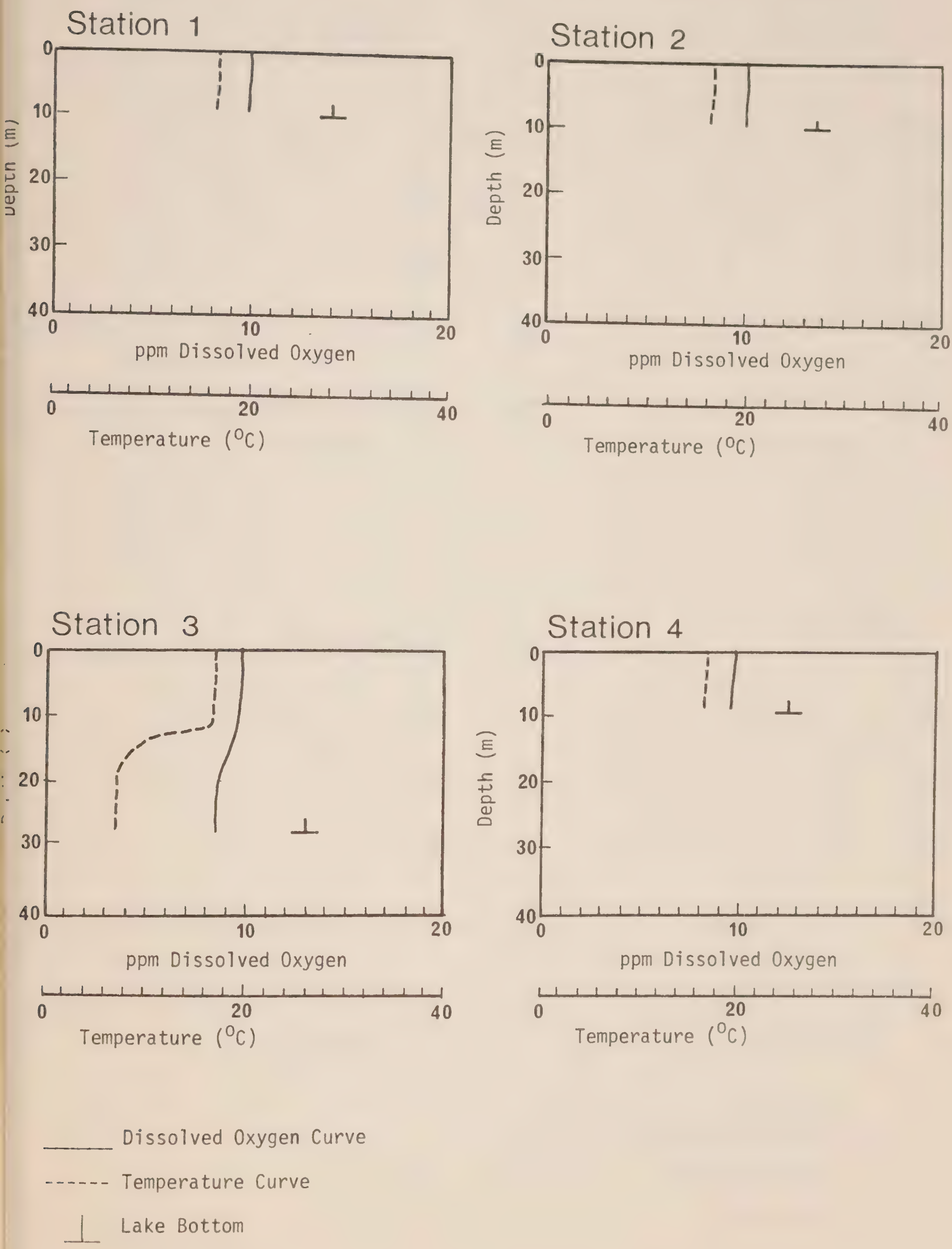
——— Dissolved Oxygen Curve

------ Temperature Curve

⊥ Lake Bottom

Dissolved Oxygen - Temperature Profiles

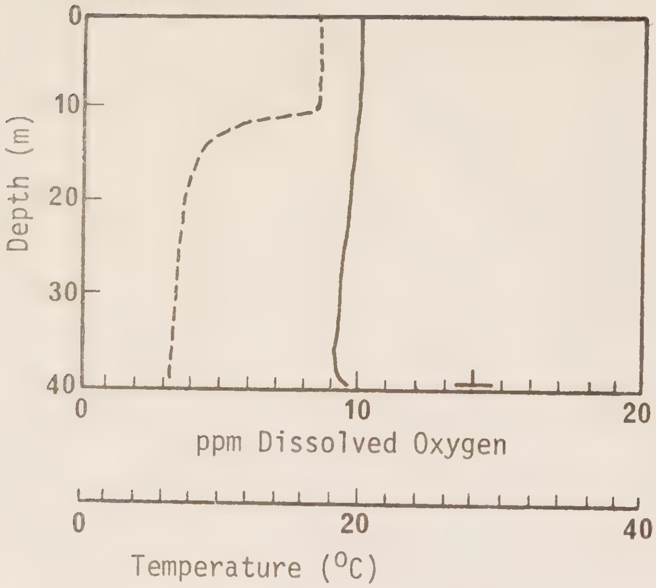
Trout Lake September 16 1977



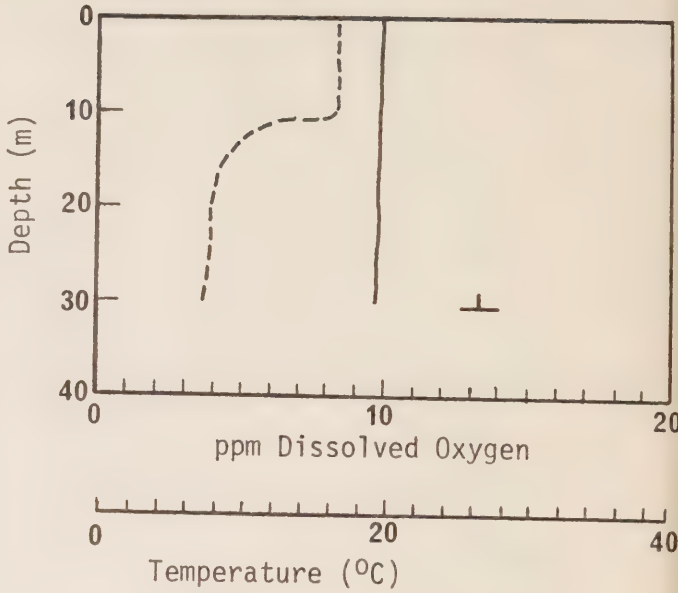
Dissolved Oxygen - Temperature Profiles

Sept 16

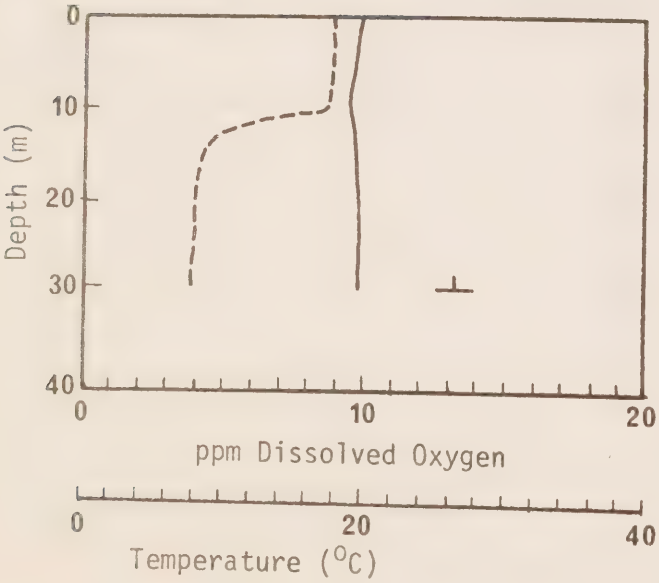
Station 5



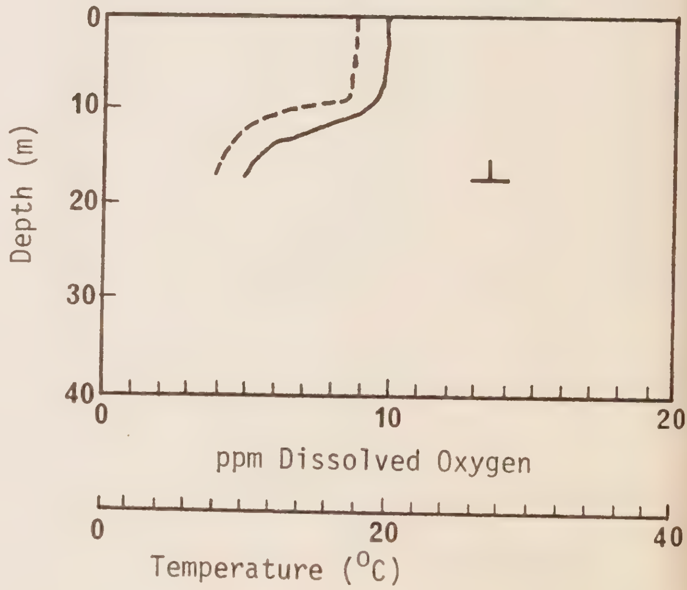
Station 6



Station 7



Station 8



——— Dissolved Oxygen Curve

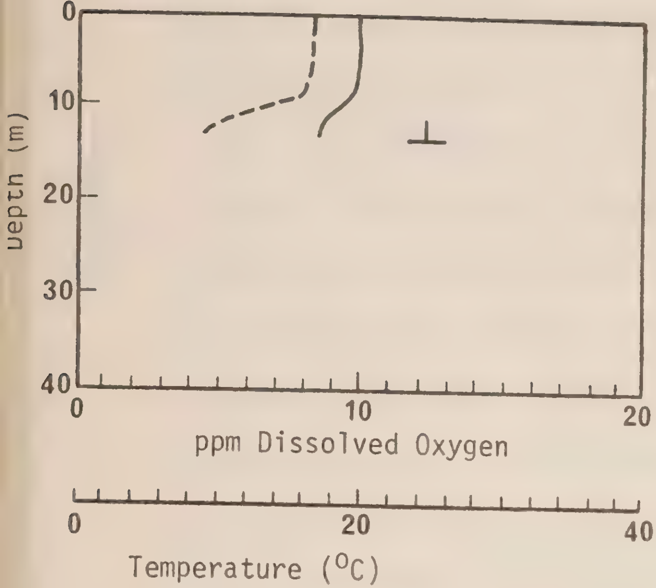
------ Temperature Curve

⊥ Lake Bottom

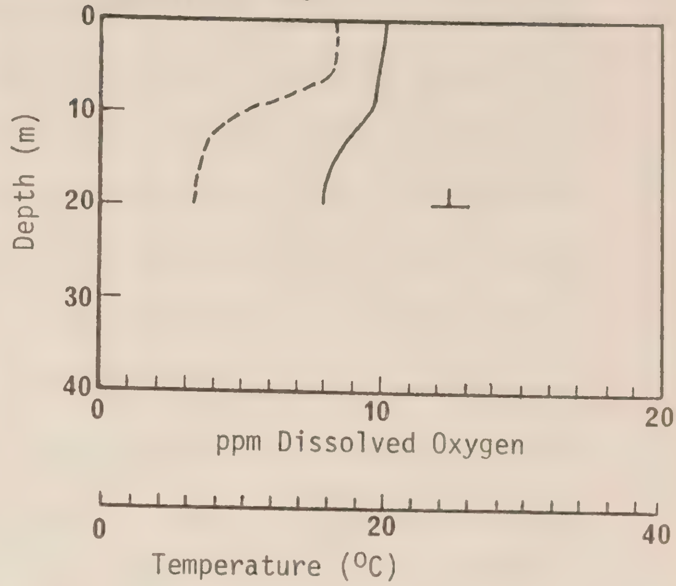
Dissolved Oxygen - Temperature Profiles

Sept 16

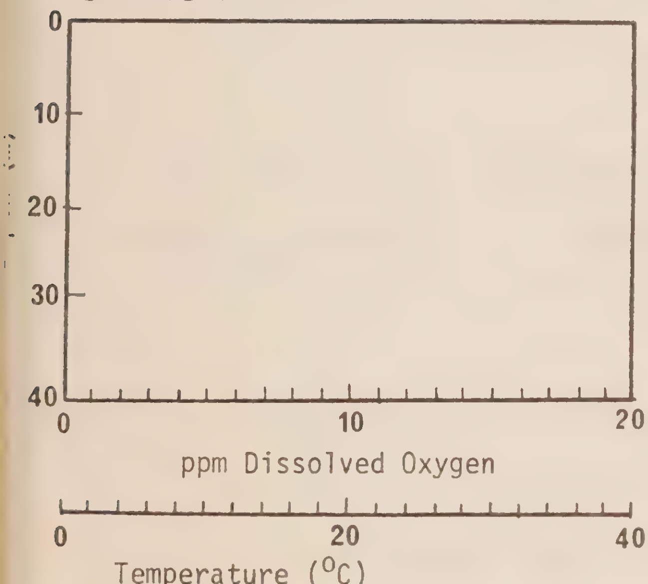
Station 9



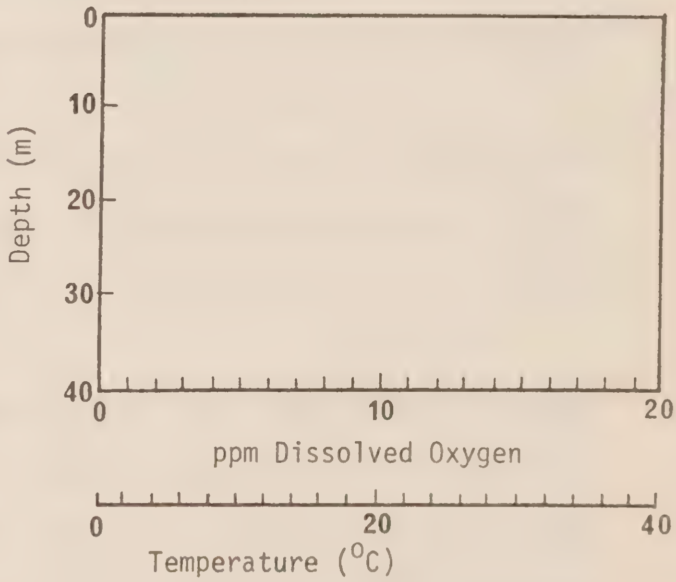
Station 10



Station



Station



______ Dissolved Oxygen Curve

------ Temperature Curve

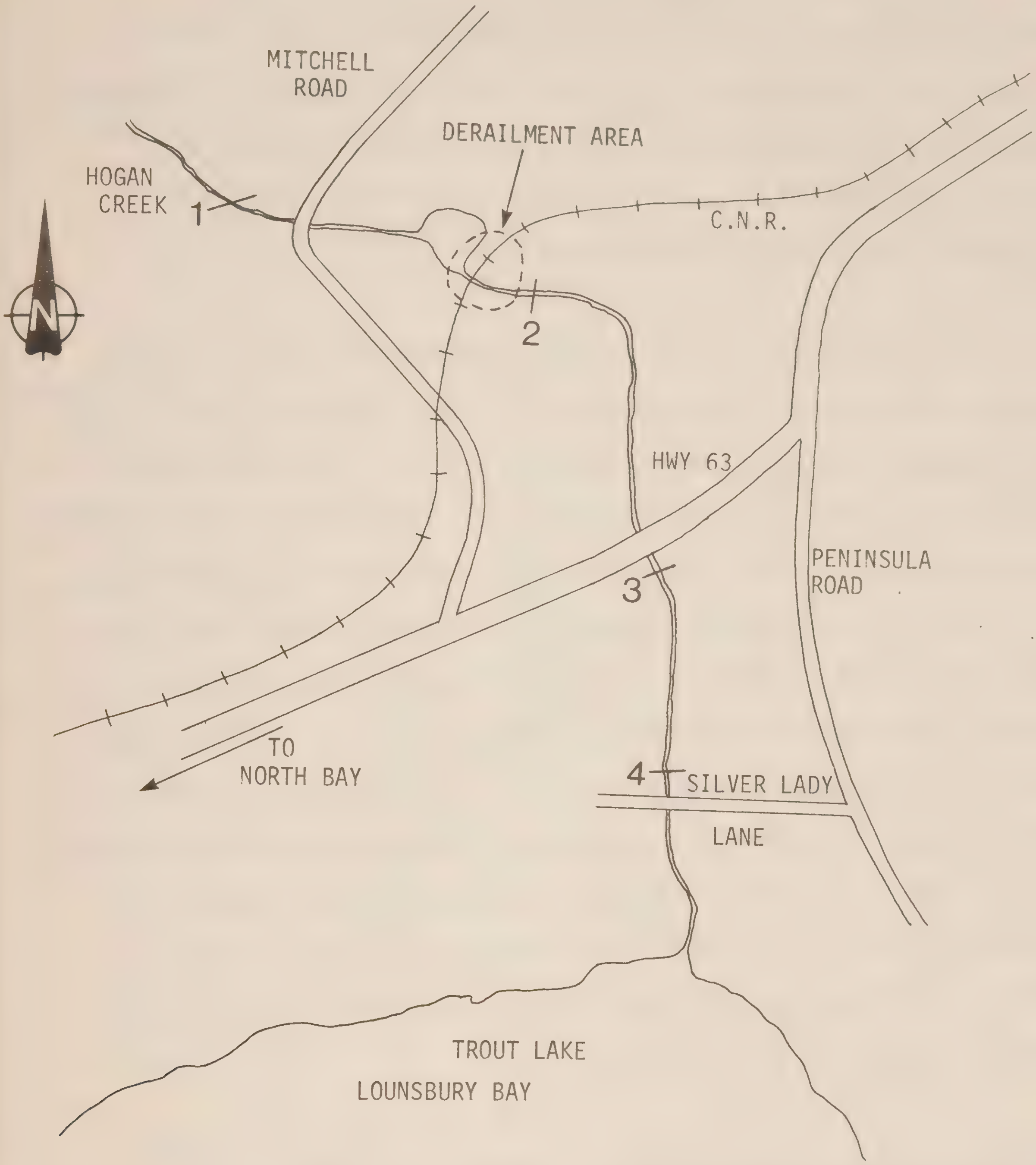
⊥ Lake Bottom

WATER QUALITY OF HOGAN CREEK

The observations of local residents during 1974 that biological life had disappeared in the lower reaches of Hogan Creek (S-2, Figure 2) led to an investigation of chemical water quality and the viability of biological communities. The results of the investigations in 1975 showed that severe water quality impairment and resultant elimination of biological life in the creek were attributable to leaching of biologically toxic contaminants from the site of a 1970 Ontario Northland Railway train derailment. Numerous box-cars carrying zinc-lead concentrates had overturned and although the Ontario Northland Railway did undertake a clean-up of the spilled concentrates at the time of the derailment, results of the 1975 investigations demonstrated that the clean-up was inadequate to protect Hogan Creek. Figure A-1 shows the derailment area and the location of chemical and biological sampling stations.

Impairment of water quality and elimination of aquatic life (fish, macroinvertebrates) was apparent from sampling location 2 down to Lounsbury Bay.

Commencing in 1977, the ONR undertook extensive additional clean-up which involved complete removal of the track bed embankments, removal of contaminated soils adjacent to the trackage and a re-routing of Hogan Creek around the contaminated area. Clean-up operations were completed in July 1978. Water quality monitoring during, and after clean-up showed a slight downstream reduction in zinc concentrations; however, levels remained very high and of continuing concern relative to their potential impact on aquatic biota.



Ministry of The Environment
Water Resources Assessment
N. E. Region

SKETCH MAP OF
HOGAN CREEK

SHOWING SAMPLING
STATION LOCATIONS

Date:	Scale	Fig. No.
Prepared By:		A-1

The results of water sampling on June 22 and August 24, 1978, are shown in Table K. The data provided are similar to analyses obtained by North Bay District Industrial Abatement staff during a continuous monitoring program which indicates continuing elevations of dissolved materials, notably zinc in Hogan Creek below the spill site.

It is important to note that the greatest elevations in zinc concentrations, and in concentrations of other materials such as sulphate occurred at stations #3 and #4, a considerable distance downstream of the spill site. Station #2, immediately below the spill site, had measurably elevated concentrations of certain contaminants; however, levels were much lower than those recorded further downstream. This indicates that, at present, the major input of contaminants to the creek occurs at a point somewhere below the spill site and not immediately adjacent to it as would be expected. The cause of this anomaly is not known at present; however, it may be a reflection of presently undetected subsurface seepage from the spill zone or continuing inputs to the creek water from the highly contaminated sediments in the stream bed.

Investigations of bottom fauna communities (Table L) support the results of water quality analyses. The invertebrate community at station #2 (just below the spill site) showed marked improvement in 1978, over the conditions (complete absence of biota) noted during earlier surveys. During 1978, a reasonably diverse benthic community, including representatives of pollution intolerant Ephemeroptera (mayflies) and Plecoptera, (stoneflies) existed at this location. Although significant recolonization

TABLE K

RESULTS OF WATER ANALYSES,
HOGAN CREEK, 1978

PARAMETER	STATION 1		2		3		4	
	June 22	Aug. 24	June 22	Aug. 24	June 22	Aug. 24	June 22	Aug. 24
pH	6.95	6.88	6.40	6.87	6.55	6.85	6.65	6.87
Conductivity	51	45	54	48	106	100	112	100
Alkalinity	10	12	6	10	9	8	9	9
Acidity	2.81	-	4.80	-	10.3	-	7.25	-
Hardness	-	16	-	17	-	32	-	32
Sodium	1.6	-	1.8	-	2.6	-	3.7	-
Potassium	0.95	-	1.10	-	1.85	-	1.65	-
Calcium	4.8	5.0	5.4	5.2	9.4	9.2	9.2	9.2
Magnesium	1.15	0.95	1.45	1.05	2.50	2.25	2.40	2.20
Sulphate	12.5	11.5	23.0	13.0	40.0	35.0	38.0	35.0
Chloride	-	0.4	-	0.4	-	0.5	-	2.0
Ammonia	-	0.018	-	0.004	-	0.008	-	0.008
Kjeldahl	-	0.29	-	0.32	-	0.26	-	0.20
Nitrate	-	0.070	-	0.070	-	0.110	-	0.125
Nitrite	-	0.003	-	0.002	-	0.002	-	0.002
Total Phosphorus	-	0.008	-	0.019	-	0.010	-	0.010
Susp. Solids	0.3	-	107	-	185	-	82	-
Diss. Solids	33	-	35	-	69	-	73	-
Turbidity	0.4	-	28	-	72	-	40	-
Apparent Colour	-	34	-	37	-	34	-	32
Iron	0.12	0.15	2.9	0.39	11	0.39	4.6	0.34
Copper	0.04	0.02	0.08	0.02	0.10	0.05	0.10	0.05
Nickel	<0.02	<0.02	<0.02	0.04	<0.02	<0.02	<0.02	<0.02
Lead	<0.03	<0.03	0.04	<0.03	0.13	<0.03	0.08	<0.03
Zinc	<0.01	<0.01	1.9	0.30	5.0	4.9	4.4	5.0
Cadmium	<0.005	<0.005	0.005	<0.005	0.005	0.01	0.015	0.01
Manganese	<0.02	0.04	0.10	0.05	0.18	0.13	0.12	0.12

Values in mg/L except pH (units), Conductivity (umhos/cm), Turbidity (Formazin units) and Colour (Hazen units).

TABLE L

RESULTS OF QUALITATIVE SAMPLING OF BOTTOM FAUNA
COMMUNITIES, HOGAN CREEK, 1978

TAXA	STATION 1		STATION 2		STATION 3		STATION 4	
	June 22	Aug. 24	June 22	Aug. 24	June 22	Aug. 24	June 22	Aug. 24
Ephemeroptera (mayflies)								
Baetidae	X	X		X				
Heptagenidae	X	X						
Plecoptera (stoneflies)								
Perlodidae			X					
Trichoptera (caddisflies)								
Hydropsychidae				X				
Rhyacophilidae	X	X	X		NO ORGANISMS FOUND	NO ORGANISMS FOUND	NO ORGANISMS FOUND	NO ORGANISMS FOUND
Diptera (true flies)								
Simuliidae	X		X					
Tendipedidae	X	X						
Unidentified		X						
Coleoptera (beetles)								
Elmidae			X					

Results based on one man/hour sampling effort at each station

has occurred at station #2, the downstream stations (#3 and #4) continued to show a complete absence of invertebrates - attributable to the more highly contaminated condition of this reach of the creek. It should be noted that despite much improvement, the aquatic biological community at station #2 remains depressed in comparison to the community upstream of the spill site. Although some pollution intolerant organisms were found at this location, very low abundance was observed.

In summary, it appears that the cleanup operations have resulted in significantly improved water quality, and correspondingly improved benthic populations, in the reach of Hogan Creek adjacent to the spill site. Conditions at this point, however, have not completely returned to the background quality measured at the upstream reference location.

Although water quality monitoring by Industrial Abatement staff indicates an apparent slight decrease in zinc concentrations further downstream, the lower reach of the creek (stations #3 and #4) remains highly contaminated and complete absence of aquatic biota continues. At present, the major input of contaminants apparently occurs some distance below the spill site and may be attributable to presently undefined seepage and/or recycle from the contaminated creek sediments.

Continuation of water quality monitoring of Hogan Creek is in effect at the release of this report (1979) and investigation into the source of persisting high zinc concentrations in the lower reaches of the creek is scheduled for 1979.

PHOSPHORUS BUDGET CALCULATIONS

A prime concern of the Ministry of the Environment is to maintain acceptable water quality levels in lakes subjected to shoreline and backlot development pressures.

Water quality deteriorates with increasing quantities of algae (suspended aquatic plants) because they decrease water clarity. Upon decay, algae deplete oxygen supplies needed to support fish populations.

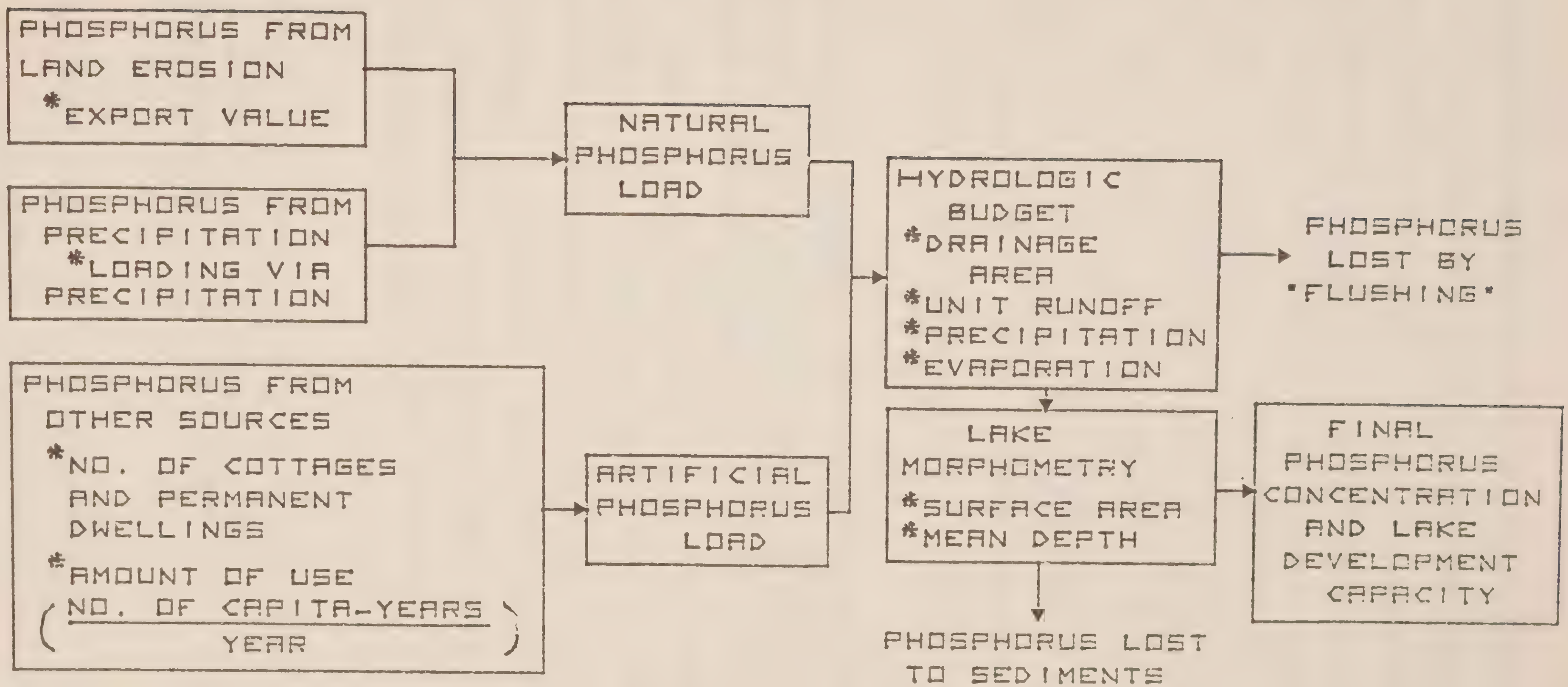
Phosphorus is the most important nutrient controlling the production of algae; so, the addition of phosphorus to a lake ultimately leads to a reduction of water quality.

Based on this concept, the average springtime phosphorus concentration can be used as an indication of the trophic status (degree of nutrient enrichment) of a lake.

A mathematical model (Dillon 1974) is used to provide a prediction of the average springtime phosphorus concentration in a lake by estimating natural and artificial (from shoreline development) inputs of phosphorus to the lake. The model is summarized in the accompanying flow diagram.

Natural inputs of phosphorus are due to the erosion and transport of phosphorus from the bedrock and surface soils, as well as dry fallout of dust containing phosphorus combined with phosphorus "washed" from the atmosphere via precipitation. Estimates of these inputs are shown in the key. The natural

DILLON'S MODEL



* INDICATES AN INPUT PARAMETER

phosphorus supply (Jn) is determined using the following equations:

$$\text{SUPPLY FROM LAND EXPORT} = \frac{E \times Ad}{10^6} = J_E \text{ (kg/yr)}$$

$$\text{SUPPLY VIA PRECIPITATION} = \frac{Lpr \times Ao}{10^6} = Jpr \text{ (kg/yr)}$$

$$Jn = J_E + Jpr$$

Where E is the land export value from the key, Ad is the lake's drainage area, Ao is the lake's surface area, and Lpr is the loading via precipitation (75 $mg/m^2/yr$).

Artificial phosphorus inputs originate primarily from human wastes, although detergents and fertilizers may contribute some phosphorus also. In order to calculate the artificial phosphorus inputs some assumptions must be made. On the average each person excretes about 0.8 kg of phosphorus per year, all of which is assumed to eventually enter the lake. In Ontario, an average of 3.9 people per household per year and 0.77 people per cottage per year are assumed. The artificial phosphorus supply (Ja) from houses and cottages can then be calculated as:

$$Ja = (N_d \times 3.9 + N_c \times 0.77) \times 0.8 \text{ (kg/yr)}$$

Where N_d is the number of houses and N_c is the number of cottages.

The total phosphorus supply (J_t) is simply the sum of the artificial and natural phosphorus supplies:

$$J_t = J_a + J_n$$

However, much of the phosphorus supply to the lake goes directly into lake sediments or is transported farther downstream of the lake's outflow. Thus the hydrologic budget and retention capacity of a lake must be estimated before arriving at a final effective phosphorus concentration.

To determine a lake's hydrologic budget the total outflow volume (Q) must be found. It is calculated as the sum of the input of water to the lake from runoff (Ad.r) and water input directly to the lake (Ao [Pr - Ev])

$$Q = Ad.r + Ao\ (Pr - Ev)$$

Where r is the unit runoff in m/yr., Pr is the mean annual precipitation in m/yr and Ev is the mean annual evaporation in m/yr.

The lake's flushing rate (F) is found as:

$$F = \frac{Q}{Ao \times \bar{Z}}$$

where Z is the lake's mean depth in m.

The retention of phosphorus by the lake is determined by the retention coefficient which is highly correlated with the areal water loading (Qs) where:

$$Q_s = Q/Ao$$

and the retention coefficient (R) is:

$$R = \frac{13.2}{13.2 + Qs}$$

If there is an upstream lake on the watershed it will retain some of the phosphorus from its drainage area. For each upstream lake the retention coefficient of the upstream lake is used to reduce the phosphorus supply to the inflow of the next lake.

The final predicted average springtime phosphorus concentration in the lake is calculated from:

$$[P] = \frac{(1 - R) \times J_t \times 10^6}{\bar{Z} \times F \times Ao}$$

To estimate the effect of any new development, the additional phosphorus supply is calculated and the new total phosphorus supply (J_t) is substituted back in the above equation to give another predicted springtime phosphorus concentration.

In the Northeastern Region, the new total phosphorus supply is calculated incrementally for two development types (full time dwellings and seasonal cottages). Calculations are performed on a Hewlett Packard 9825A programmable calculator and outputted in both printed and plotted form showing development capacity for the existing level of water quality.

The basis of Dillon's model is the <u>theoretical springtime phosphorus</u> concentration which is obtained by estimating natural and artificial phosphorus supplies. Because of uncertainty regarding the agreement of theoretical spring

phosphorus predictions with actual analytical determinations of spring phosphorus and the independence of the measured concentrations from possible "estimation" errors, the actual measured springtime phosphorus concentration of a lake is preferred as the base for the determination of development capacity. Theoretical concentrations are computed for comparison.

KEY

SYMBOL	MEANING	UNITS
Z	Mean depth of lake	m
Ao	Lake surface area	m^2
Ad**	Lake drainage area	m^2
Jn	Natural phosphorus supply	kg/yr
Ja	Artificial phosphorus supply	kg/yr
Jt	Total phosphorus supply	kg/yr
Nd	Number of houses	
Nc	Number of cottages	
Q	Total outflow volume	m^3/yr
r	Unit runoff	m/yr
Pr	Mean annual precipitation	m/yr
Ev	Mean annual evaporation	m/yr
F	Flushing rate	times/yr
Qs	Areal water load	m/yr
R	Retention coefficient	
Lpr	Phosphorus loading via precipitation	75 mg/m^2/yr
E*	Land export value derived from Table I	mg/m^2/yr

* TABLE I: AVERAGE EXPORT VALUES (mg/m^2/yr)

GEOLOGICAL CLASSIFICATION

LAND USE		IGNEOUS	SEDIMENTARY
Forest	Range	0.7 - 8.8	6.7 - 18.3
	Mean	5.5	10.3
Forest & Pasture	Range	5.9 - 16.0	11.1 - 37.0
	Mean	9.8	19.8

NOTE: When E is in the 5.5 mg/m^2/yr category, the export value should be calculated as follows:

$$E = 1.32 + 5.54\ Dd$$

Where Dd is the "drainage density" and

$$Dd = \frac{\text{(Length of Each Input Stream)}}{Ad} \qquad (km^{-1})$$

** Drainage area of a lake is found by planimetry of watershed drawn on topographic maps.

ONTARIO MINISTRY OF THE ENVIRONMENT - NORTHEAST REGION

LAKE DEVELOPMENT CAPACITY - DILLON'S MODEL

LAKE: TROUT

TWP.: BONFIELD

DATE: MAR 1979

SUMMARY: This lake is classified as a Level 1 lake. This means that the Spring Phosphorus Concentration ranges from 0.0 to 9.9 mg/cu.m. A maximum of 68 cottages or 13 permanent dwellings may be added to maintain a Level 1 classification.

The addition of 341 cottages or 67 permanent dwellings will result in a 1 mg/cu.m increase in the existing Spring Phosphorus Concentration.The full effect of any extra Phosphorus loading will be noticed after 3.9 years.

SUPPORTING DATA:

Lake Area(sq.m): 13677565
Drainage Area(sq.m): 57636236
Mean Depth(m): 17.21
Volume(cu.m): 235390894
Unit Runoff(m/yr):0.4490
Precipitation(m/yr): 0.86
Evaporation(m/yr): 0.56
Total Outflow Volume(cu.m): 30050327
Flushing Rate(Lake's vol./yr): 0.1277
Retention Coefficient(R):0.8573
Response Time(yr): 2.3 to 3.9

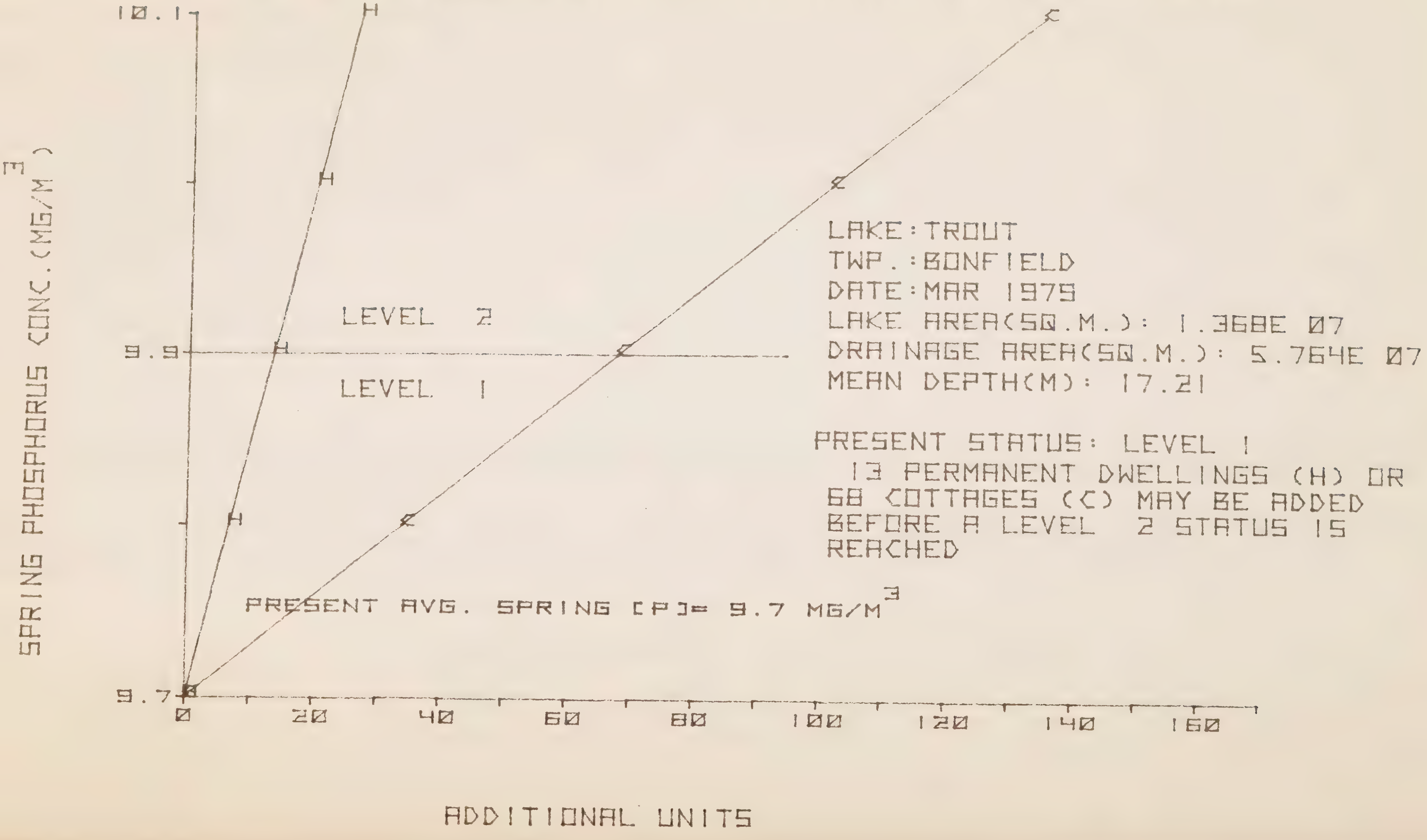
Actual Phosphorus Loading(mg/sq.m/yr): 149.35
Actual Phosphorus Supply(kg/yr): 2042.76

MEASURED SPRING PHOSPHORUS CONCENTRATION(mg/cu.m): 9.7

Theoretical Phosphorus Loading(mg/sq.m/yr): 178.02
Theoretical Phosphorus Supply(kg/yr): 2434.92

THEORETICAL SPRING PHOSPHORUS CONCENTRATION(mg/cu.m): 11.6

NORTHEAST REGION M.O.E.
LAKE DEVELOPMENT CAPACITY AFTER DILLON'S MODEL



ONTARIO MINISTRY OF THE ENVIRONMENT - NORTHEAST REGION

LAKE DEVELOPMENT CAPACITY - DILLON'S MODEL

LAKE: 4-MILE BAY

TWP.: BONFIELD

DATE: MAR 1979

SUMMARY: This lake is classified as a Level 1 lake. This means that the Spring Phosphorus Concentration ranges from 0.0 to 9.9 mg/cu.m. A maximum of 202 cottages or 39 permanent dwellings may be added to maintain a Level 1 classification.

The addition of 106 cottages or 20 permanent dwellings will result in a 1 mg/cu.m increase in the existing Spring Phosphorus Concentration.The full effect of any extra Phosphorus loading will be noticed after 2.5 years.

SUPPORTING DATA:

Lake Area(sq.m): 3056186
Drainage Area(sq.m): 53984595
Mean Depth(m): 15.62
Volume(cu.m): 47737625
Unit Runoff(m/yr):0.4490
Precipitation(m/yr): 0.86
Evaporation(m/yr): 0.56
Total Outflow Volume(cu.m): 25171220
Flushing Rate(Lake's vol./yr): 0.5273
Retention Coefficient(R):0.6158
Response Time(yr): 1.5 to 2.5

Actual Phosphorus Loading(mg/sq.m/yr): 171.49
Actual Phosphorus Supply(kg/yr): 524.10

MEASURED SPRING PHOSPHORUS CONCENTRATION(mg/cu.m): 8.0

Theoretical Phosphorus Loading(mg/sq.m/yr): 218.35
Theoretical Phosphorus Supply(kg/yr): 667.33

THEORETICAL SPRING PHOSPHORUS CONCENTRATION(mg/cu.m): 10.2

NORTHEAST REGION M.O.E.
LAKE DEVELOPMENT CAPACITY AFTER DILLON'S MODEL